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VIA ELECTRONIC MAIL & FEDERAL EXPRESS

May 4, 2012

Cheryl Sprague, Remedial Project Manager
New Hampshire/Rhode Island Superfund Section
Office of Site Remediation and Restoration
United States Environmental Protection Agency
5 Post Office Square, Suite 100
Boston, Massachusetts 02109-3912

Subject: **Revised Supplemental Design Data Collection Work Plan**
Operable Unit 1
Fletcher's Paint Works and Storage Facility Superfund Site
CERCLA Docket No. 01-2001-0063
Milford, New Hampshire

Dear Ms. Sprague:

Enclosed please find the revised Supplemental Design Data Collection (SDDC) Work Plan prepared by ARCADIS, U.S., Inc. (ARCADIS) for the above-referenced site. As requested, this work plan has been modified to address the comments provided by the United States Environmental Protection Agency (EPA) in its April 24, 2012 approval letter. A document that summarizes our responses to EPA's comments is also attached. As always, please call me if you have any questions regarding this matter.

Sincerely,

Paul Wm. Hare

Paul Wm. Hare
Program Manager, Northeast/Midwest Regions

attachment
enclosure

cc: Michael Jasinski, EPA
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Ellen Iorio, ACOE
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RESPONSE TO EPA's APRIL 24, 2012 COMMENTS ON THE REVISED WORK PLAN FOR ADDITIONAL WORK TO ADDRESS CONSTRUCTABILITY ISSUES REGARDING THE OU-1 SOIL REMEDY

General: In a letter dated April 24, 2012, the United States Environmental Protection Agency (EPA) provided comments on the *Work Plan for Additional Work to Address Constructability Issues Regarding the OU-1 Soil Remedy* (Supplemental Design Data Collection [SDDC] Work Plan submitted by the General Electric Company (GE) on December 22, 2011, as revised on April 6, 2012. Responses are provided below.

EPA's April 24, 2012 Letter on the Revised SDDC Work Plan

EPA and the USACE have reviewed the revised Work Plan for Additional Work to Address Constructability Issues regarding the OU1 Soil Remedy submitted on April 6, 2012 by ARCADIS for the Fletcher's Paint Works and Storage Facility Superfund Site, located in Milford, New Hampshire. EPA has also reviewed GE's Response to EPAs comments on the December 22, 2011 submission of this report.

The only significant clarifications on the work plan relate to the proposed DNAPL sampling and bedrock well installations. The Corps has addressed these topics in their comments which are enclosed with the letter. Therefore the Work described in this Work Plan is approved by the EPA. Please keep all parties (EPA, Corps, NHDES, Town) appraised of the on-going work. A quick weekly email update should be considered.

The response to comments letter included with the Work Plan described a decision tree matrix reflecting potential design consideration modifications associated with potential pump test results and which may ultimately be proposed in the remedial design. Please include this information in Section 2.10 of the Work Plan (Data Analysis).

Response: Section 2.10 of the SDDC Work Plan has been revised to incorporate a discussion regarding the possible modifications to three elements of the remedial design (i.e., the soldier pile tremie concrete [SPTC] support of excavation design, the dewatering system design, and the temporary water treatment system design) that could be modified based on the results of the hydraulic testing activities proposed in the SDDC Work Plan and the subsequent revisions to the groundwater modeling performed during the pre-design phase of the project.

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USACE's April 12, 2012 Numbered Comments on the Revised SDDC Work Plan

USACE Comment #1*:* ***RTC Summary Letter, USACE Comment #9B, p. 13/27; Work Plan Section 2.5, p. 8:***

Clarification is requested regarding the method proposed for checking and sampling for DNAPL. The revised Work Plan references use of a bottom loading bailer in addition to an interface probe to check for DNAPL during implementation of DNAPL sampling procedures (see Section IV, revised Appendix H of the FSP, July 5, 2007-attached). USACE recommends that Section IV, Step 3 (lower intake and end of [peristaltic] pump tubing to the bottom/base of well) be followed regardless of what is observed when checking for DNAPL using the interface probe and bailer. USACE is concerned that sampling *effort may be terminated after checking the well with the bailer. Previous attempts at DNAPL sampling at MW-21C indicated that methods for checking could be unreliable at best, and that due diligence justified attempted to sample with the peristaltic pump before a reasonable conclusion that no DNAPL could be sampled at that time. Based on previous observations and sampling experiences at MW-21C, we recommend that Section IV of the revised Appendix H be followed to completion through Step 6 of this procedure on all wells to be inspected and attempted for sampling of DNAPL.*

Response: Sections 2.5, 2.6.3, and 2.9 of the SDDC Work Plan have been revised to indicate an interface probe, bottom-loading bailer, and a peristaltic pump will be used to check for the potential presence of dense non-aqueous phase liquid (DNAPL) in the subject wells as part of the baseline and post-hydraulic testing DNAPL monitoring activities.

* * * * *

USACE Comment #2: ***RTC Summary letter, USACE Comment #19, p. 18/27.***

Drop tube installations are described for overburden pumping well PW-1. These same procedures should be followed for bedrock pumping well PW-2.

Response: Although not discussed in the referenced response to comment, identical drop tube installations were previously proposed for both the overburden and bedrock pumping wells, as indicated on Figure B-2 of previous versions of the SDDC Work Plan. Nevertheless, as a means of further clarification, Sections 2.6.1 and 2.6.2 of the SDDC Work Plan have been revised to provide additional details regarding the drop tubes to be installed in each well.

* * * * *

USACE Comment #3: ***RTC Summary letter, USACE Comment #20, p 18/27; Fig. B-1 & B-2 Schematic of Well Design; Work Plan Section 2.6.2, p. 11.***

Bedrock monitoring well/piezometers and bedrock pumping well PW-2 are shown to be completed with grouted sumps by appearing to shorten the length of the planned open hole that would be exposed in bedrock to transmissive fractures. The grouted sump portion in these bedrock holes appears to be formed by reducing the hole depth to form the sump, rather than overdrilling additional depth to create the sump. For example, the bedrock pumping well PW-2 is proposed to be drilled by installing a 6-inch diameter casing into a 3 foot deep socket beneath the top of bedrock, and reaming an additional 15 feet into rock below the casing (total depth 18 feet into rock). The revised Work Plan notes that if fractures are observed in the bottom 5 feet of the 15 foot open borehole of PW-2, then this bottom 5 feet would be converted into a grouted sump We note that this revised plan would shorten the transmissive length of open borehole of bedrock pumping well PW-2 by 5 feet, make the effective transmissive length of the pumping well 33% shorter, and potentially reduce the pumping capacity and the radial distance at which pumping stresses may be felt in bedrock monitoring wells and piezometers (i.e.: Elm Street wells and wells north of the RR tracks).

We recommend that for either bedrock monitoring wells/piezometers (Figure B-1), or bedrock pumping well PW-2 (Figure B-2), that any grouted sump be formed by overdrilling beyond the planned original depth of the open bedrock borehole in order to provide the maximum length of the hydraulic connection between the borehole and nature bedrock fractured formation. The over-drilled length may show a lack of fractures that could be used as the sump or if also fractured be used to construct the sump without restricting the available well length. For example, if the bottom 5 feet of PW-2 is observed to be fractured, then the borehole should be reamed to a depth of 23 feet beneath top of bedrock (20 feet below bottom of 6-inch steel casing), and the bottom 5 feet of borehole could be converted to the grouted sump (18-23 feet beneath top of bedrock).

Response: Section 2.6.2 and Figure B-2 of the SDDC Work Plan have been revised to indicate that the borehole for pumping well PW-2 will be advanced by bedrock coring 3 feet into competent bedrock to install the outer casing. Once the outer casing is set, bedrock coring will continue for another 20 feet below the depth of the outer casing. If natural fractures are observed in the bottom 5 feet of the coring, the bottom 5 feet of the core hole will be filled with grout, which will be allowed to set prior to being reamed for use as a sump. If no natural fractures are observed, the core hole will remain open hole construction.

Similarly, the text of Section 2.6.3 of the SDDC Work Plan has been revised to indicate that bedrock monitoring wells MW-08C, MW-31C, and MW-32C would have similar construction as temporary bedrock piezometer PZ-07C. Specifically, the borehole for each well will be advanced by bedrock coring 3 feet into competent bedrock to install the outer casing. Once the outer casing is set, bedrock coring will continue for another 13 feet below the depth of the outer casing. If natural fractures are observed in the bottom 3 feet of the coring for PZ-07C and MW-08C, a 3-foot long stainless steel sump will be installed using the procedures specified in the SDDC Work Plan; otherwise the temporary piezometer/monitoring well will remain open hole construction. Since DNAPL is not expected to be observed at monitoring wells MW-31C and MW-32C, those wells will remain open hole construction (similar to monitoring wells MW-25C and MW-30C) regardless of whether natural fractures are observed in the bottom 3 feet of the core.

* * * * *

USACE's Comment #4: ***Figure 1.***

Can the site boundaries for the property line/footprint of the Elm Street Area and Mill Street Area sites, with the two areas labeled so as to be clear to third parties what are the property boundaries for the two areas, be shown on Figure 1, similar to what is shown property line boundaries for these two areas on Figure 2 of the quarterly Water Monitoring Reports.

Response: Figure 1 of the SDDC Work Plan has been revised as requested.

* * * * *

USACE Comment #5: *Work Plan, Section 3, p. 17, § 3.*

Reference is made the "28 composite soil samples and five grab samples for analysis of PCBs from the locations shown on Figure 2." Should the figure reference be Figure 3 of the Work Plan?

Response: Correct. The subject text has been revised as noted.

* * * * *

USACE Comment #6: *Figure B-2 & Assoc. Text*

Please clarify that the 1.5 inch drop tube for DNAPL monitoring will be open ended and suspended a min. of 0.3 feet above the bottom of the well. Also recommend that this DNAPL monitoring drop tube have a screen slot size much larger than 0.020 as shown. Recommend use of no less than a 0.2 inch slot size to ensure the screen does not control potential DNAPL detection/sampling.

Response: Sections 2.6.1, 2.6.2, and Figure B-2 of the SDDC Work Plan have been revised as requested.

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DRAFT

FOR EPA REVIEW

Work Plan for Additional Field Work Necessary to Address Constructability Issues Regarding the OU-1 Soil Remedy

Fletcher's Paint Works and Storage Facility
Superfund Site
Milford, New Hampshire

December 22, 2011

Revised April 6, 2012 and May 4, 2012

DRAFT

FOR EPA REVIEW

Work Plan for Additional Field Work Necessary to Address Constructability Issues Regarding the OU-1 Soil Remedy

Fletcher's Paint Works and Storage Facility Superfund Site

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Our Ref.:

B0030945.2011

Date:

December 22, 2011

Revised April 6, 2012 and May 4, 2012

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1. Introduction

On December 31, 2007, the General Electric Company (GE) submitted to the United States Environmental Protection Agency (EPA) a draft *Final (100%) Design Report for the OSD Remedy* (Final Design Report) for Operable Unit 1 (OU-1) of the Fletcher's Paint Works and Storage Facility Superfund Site (the Site) located in Milford, New Hampshire. As approved by EPA, the Final Design Report did not include a Constructability Review Report or Final Bid Documents. GE made several subsequent submittals providing revisions, modifications, and/or additional information for certain elements of the remedial design. On September 30, 2011, EPA approved, with modifications, the Final Design Report and requested a meeting to discuss EPA's comments to that document, as well as outstanding issues relating to the submission of a revised Final Design Report, the Constructability Review Report and Final Bid Documents.

Representatives of EPA, the New Hampshire Department of Environmental Services (NHDES), the United States Army Corps of Engineers (ACOE) and GE met on November 8, 2011. During that meeting EPA extended the deadline for GE's submission of arevised Final Design Report, the Constructability Review Report and the Final Bid Documents specified in paragraph 85(B) of the Unilateral Administrative Order for Remedial Design and Remedial Action with Second Modifications (UAO), and GE agreed to make certain additional submittals to EPA not specified in the UAO on or before December 22, 2011. One of those submittals was the *Work Plan for Additional Field Work Necessary to Address Constructability Issues Regarding the OU-1 Soil Remedy* (Work Plan) prepared by ARCADIS U.S., Inc. (ARCADIS). EPA and ACOE subsequently provided comments on the Work Plan in a letter to GE dated February 17, 2012. Following receipt of that letter, representatives of EPA, ACOE, NHDES, GE, and ARCADIS participated in conference calls to discuss EPA's and ACOE's comments on the Work Plan. Specifically, a conference call was held on February 29, 2012 to discuss comments on the soil characterization and pre-construction verification sampling activities proposed in the Work Plan, and a second call was held on March 7, 2012 to discuss comments on the hydraulic testing activities proposed in the Work Plan. EPA submitted additional comments on the Work Plan via electronic mail on March 23, April 2, and April 4, 2012. This revised Work Plan addresses EPA's comments to the Work Plan.

Implementation of this Work Plan will result in additional data that will reduce uncertainties associated with three elements of the OU-1 soil remedy: (1) the dewatering rate for the deeper excavation cells (i.e., within the soldier pile tremie concrete [SPTC] walls) at the Mill Street Area; (2) side-wall verification sampling on the passive sides of vertical excavation supports at the Elm Street Area (as specified in the Verification Sampling Plan [VSP, Appendix A of the Final Design Report]); and (3) soil characterization to determine the appropriate off-site treatment and/or disposal of excavated materials. Additional details regarding the data collection activities designed to reduce each of these uncertainties are provided in the following sections.

Reducing these uncertainties could have a significant impact on the sequencing, implementation, schedule, and cost of the OU-1 soil remedy.

Certain of the supplemental design data collection activities (e.g., installation of pressure transducers in monitoring wells MW-09A and MW-09B, installation of soil borings and soil sampling, and management of groundwater from installation and development of pumping wells and temporary piezometers and hydraulic testing) would occur on Parcel 25-110. The owner of Parcel 25-110 previously provided access for pre-design investigation activities and provided access for ongoing quarterly groundwater monitoring activities up to and including the January 2012 sampling event. However, as noted during the November 8, 2011 meeting with EPA, GE did not have access from the property owner for implementation of the OU-1 soil remedy, and did not have access for implementation of this Work Plan or for future quarterly groundwater monitoring activities. However, with EPA's assistance, GE has recently reached agreement with the owner of Parcel 25-110 and anticipates receiving the executed access agreement during the week of April 30, 2012. In addition, GE does not currently have access for certain activities that would occur on Parcel 25-112 (installation of monitoring well MW-08C). If the executed access agreement for Parcel 25-110 is not received and/or if access is not obtained to Parcel 25-112, the Work Plan activities and/or schedule for implementation will require modification.

2. Hydraulic Testing

2.1 Estimated Dewatering Rates for the Mill Street Area

The database of hydraulic conductivity data collected at the Mill Street Area during the pre-design investigation formed the basis for the estimated dewatering rates that were calculated using the United States Geological Survey (USGS) modular, three dimensional, finite-difference groundwater flow model, also known as MODFLOW (McDonald and Harbaugh, 1988) as part of the remedial design for the Site. A *Groundwater Modeling Report* presenting the results of the modeling was included as Appendix B of the November 2005 *Preliminary (30%) Design Report.* Those estimated dewatering rates subsequently formed the basis for: (1) the hydraulic barrier/support of excavation design for excavations extending below the water table at the Mill Street Area (i.e., the selection, configuration, and design of the SPTC walls); (2) the design of the dewatering systems for the excavation cells; and (3) the design of the temporary water treatment system. However, the previous measurements of hydraulic conductivity were based on single-well specific capacity test data collected during well development and low-flow groundwater sampling activities. Given the nature of the OU-1 remedial activities anticipated at the Mill Street Area (i.e., excavation to bedrock, which is up to 15 feet below the elevation of the water table), the influence of hydraulic conductivity on predicted dewatering rates, and the influence of the predicted dewatering rates on several key elements of the remedial design, a more robust analysis of the hydraulic conductivity and predicted dewatering rates at the Mill Street Area is necessary.

The supplemental hydraulic testing activities include longer duration, higher pumping rate single-well specific capacity tests and larger-scale pumping tests. These tests will be performed to further evaluate the hydraulic conductivity of the overburden and bedrock and their impact on the predicted pumping rates required to dewater certain excavations at the Mill Street Area during the OU-1 soil remedy. To the extent possible, these hydraulic testing activities will not be completed during or immediately after any significant rainfall events. Upon completion of the additional hydraulic testing, the hydraulic conductivity estimates for the overburden and bedrock at the Mill Street Area will be revised and the groundwater flow model previously developed for the Site will be re-calibrated. The re-calibrated groundwater flow model will then be used to refine the estimated dewatering rates that could be necessary during excavation dewatering. The remainder of this section provides additional details regarding the activities associated with implementation of the specific capacity testing and pumping tests. A table presenting the schedule (with estimated durations) for each of the significant activities is provided in Appendix A.

2.2 Existing Monitoring Well Redevelopment

In preparation for the hydraulic testing activities, 11 existing monitoring wells located within approximately 100 feet of the pumping well locations discussed in Section 2.6 will be redeveloped. These monitoring wells include: MW-07A, MW-21C, MW-22A, MW-22B, MW-22C, MW-23A, MW-23B, MW-23C, MW-24A, MW-24B, and MW-24C. Redevelopment will help ensure that these wells, which may have drawdown values as small as 0.1 feet during the hydraulic testing, are connected to the formation prior to the specific capacity, step-drawdown and, constant-rate pumping tests. Redevelopment will be conducted in accordance with Appendix E of the *Field Sampling Plan* (FSP), Volume 2 of the *Sampling and Analysis Plan* (SAP) included in the *Project Operations Plan* (POP) (Blasland, Bouck & Lee, Inc. [BBL, now part of ARCADIS], June 2003, as amended), entitled "Monitoring Well Installation and Development Procedures". Purge water generated during well development will be managed as described in Section 6.

2.3 Pressure Transducer Installation/Logging and Meteorological Monitoring

Pressure transducers will be installed at several locations at least one week prior to the drilling activities for the new piezometers, monitoring wells, and pumping wells, as described in Sections 2.4 and 2.6. Specifically, 42 pressure transducers will be installed at the following locations shown on Figure 1:

- Eleven (11) existing monitoring wells subject to specific capacity testing (i.e., MW-07A, MW-21C, MW-22A, MW-22B, MW-22C, MW-23A, MW-23B, MW-23C, MW-24A, MW-24B, and MW-24C;

- Fourteen (14) existing monitoring wells not subject to specific capacity testing (i.e., MW-04A, MW-04B, MW-04C, MW-06B, MW-06C, MW-08A, MW-08B, MW-09A, MW-09B, MW-10A, MW-10B, MW-10C, MW-26A, and MW-30C);

- The box culvert where the drainage ditch from Mill Pond passes beneath the railroad tracks adjacent to the Mill Street Area,

- Staff gauge SG-1 installed in the Souhegan River next to the Elm Street Area;

- A temporary piezometer manually pushed into the river bed adjacent to staff gauge SG-1; and

- A background shallow overburden/bedrock well cluster (i.e., MW-11A, MW-11B and MW-11C).

These transducers, which will be programmed to measure water levels every five minutes, are expected to provide several weeks of data prior to the initiation of the specific capacity and pumping tests.

In addition to the transducers described above, 11 transducers will also be placed in the following new temporary piezometers, monitoring wells, and pumping wells that will be installed in support of the hydraulic testing activities described in this Work Plan:

- Temporary piezometers PZ-07B, PZ-07C, PZ-21A, and PZ-21B;
- Monitoring wells MW-08C, MW-31C, MW-32A, MW-32B, and MW-32C; and
- Pumping wells PW-1 and PW-2.

At a minimum, all transducers will record water level data for approximately one week prior to initiation of the specific capacity testing (described in Section 2.7) to characterize background water level trends. Finally, the transducers will continue recording water levels until at least one week after the completion of the second constant-rate pumping test (described in Section 2.8).

In addition, barometric pressure and precipitation readings will be recorded during the hydraulic testing program. Barometric pressure will be measured using an on-site automatic logger that will collect measurements at the same frequency as the water level measurements obtained from the transducers installed in the monitoring wells and piezometers. Precipitation readings will be recorded using an on-site rain gauge.

2.4 Installation of Temporary Piezometers and Monitoring Wells

Several temporary piezometers and monitoring wells will be installed in support of the hydraulic testing activities described in Sections 2.7 and 2.8. Specifically, three temporary overburden piezometers, one temporary bedrock piezometer, one overburden monitoring well, and one bedrock monitoring well will be installed, developed, and sampled prior to the overburden/bedrock pumping tests. Two of the temporary overburden piezometers (PZ-21A and PZ-21B) will form a triplet with existing bedrock monitoring well MW-21C. A third overburden temporary piezometer (PZ-07B) and the temporary bedrock piezometer (PZ-07C) will form a triplet with existing overburden monitoring well MW-07A. In addition, new overburden and bedrock monitoring wells MW-32A, MW-32B, and MW-32C will be installed on Parcel 25-114 (i.e., the American Legion property) and bedrock monitoring wells MW-08C and MW-31C will be installed on Parcels 25-112 and 25-133, respectively (subject to securing access to Parcel 25-112). The locations for the new monitoring wells and temporary piezometers are shown on Figure 1. Figure 2 also shows the locations of the new temporary piezometers and monitoring well MW-08C. Additional details regarding the installation, survey, and development of these piezometers and monitoring wells are provided in the following subsections. Information regarding water quality sampling and dense non-aqueous phase liquid (DNAPL) monitoring are provided in Sections 2.5 (baseline sampling/monitoring) and 2.9 (post-hydraulic testing sampling/monitoring).

2.4.1 Installation of Temporary Overburden Piezometers

The borings for new temporary overburden piezometers PZ-07B, PZ-21A, and PZ-21B will be advanced to the appropriate depth within the overburden using 6-inch diameter flush-joint casing and drive and wash drilling techniques. Continuous split-barrel sampling will be performed only during the drilling of the PZ-21A borehole and in accordance with the procedures specified in Appendix A of the FSP, entitled "Soil Boring Installation and Soil Sampling Procedures." Recovered soil samples from that borehole will be logged and characterized as also described in Appendix A of the FSP. In addition, one or two representative soil samples will be collected from the borehole for PZ-21A for grain size analyses.

In general, the temporary overburden piezometers will be constructed in accordance with the procedures specified in Appendix E of the FSP, entitled "Monitoring Well Installation and Development Procedures". Specifically, the temporary piezometers will be constructed using 2-inch diameter, flush-threaded, schedule 40 polyvinyl chloride (PVC) pipe with 0.010-inch slot screens and filter packs consisting of Morie #0 (or equivalent) silica sand. However, for temporary piezometer PZ-21A, the 5-foot screen will be installed at the base of the overburden. The 5-foot screens for temporary piezometers PZ-07B and PZ-21B will each be installed with the top of the screen positioned at the approximate seasonal average water-table elevation (approximately 253.2 feet above mean sea level [amsl] at MW-07A and 252.6 feet amsl at MW-21C). A schematic of the overburden piezometer design is provided as Figure B-1 of Appendix B.

2.4.2 Installation of Temporary Bedrock Piezometer

The boring for the installation of new temporary bedrock piezometer PZ-07C will be advanced to the top of competent bedrock (auger refusal) using drive and wash drilling techniques with continuous split-barrel sampling as described in Appendix A of the FSP. Recovered soil samples will be logged and characterized as discussed in Appendix A of the FSP. Similar to the overburden piezometers, one or two representative soil samples will be collected for grain size analysis from the borehole for PZ-07C.

A nominal 6-inch outer diameter (OD) roller bit will be used to drill a socket 3 feet into the top of competent bedrock. A 4-inch diameter black steel casing will be lowered to the bottom of the socket and grouted in place to the ground surface using neat cement grout via the tremie method. After allowing the grout to cure for a minimum of 12 hours, or as otherwise specified by the manufacturer, the borehole will be advanced 13 feet below the steel casing by continuously coring the bedrock using the bedrock drilling methods described in Appendix E of the FSP. Following bedrock coring, a nominal 3- to 4-inch OD roller bit will be used to ream the core hole to approximately 13 feet below the bottom of the steel casing. The temporary bedrock piezometer will be completed using an open-hole construction, with the bottom 3 feet serving as a sump at the bottom of the well. However, if natural fractures are observed in the bottom 3 feet of the core, the sump will be constructed using a 3-foot section of stainless steel pipe, grouted in place. If necessary, such a sump will be installed by carefully pumping a volume of grout to the bottom of the borehole that is slightly greater than the annular space between the sump and core hole wall. Next, the sump and grout basket will be installed by pushing the sump through the grout to the bottom of the borehole. Water and any excess grout that enter the sump will then be promptly bailed or pumped from that sump. A schematic of the bedrock piezometer design is provided as Figure B-1 of Appendix B.

2.4.3 Installation of Overburden and Bedrock Monitoring Wells

As previously indicted, the MW-32 monitoring well cluster (i.e., MW-32A, MW-32B, and MW-32C) will be installed on Parcel 25-114 (i.e., the American Legion property) located between the Mill Street Area and the Elm Street Area (Figure 1). In addition, bedrock monitoring wells MW-08C and MW-31C will be installed on Parcels 25-112 and 25-133, respectively (subject to securing access to Parcel 25-112). Continuous split-barrel sampling will only be performed during drilling of the MW-08C, MW-31C, and MW-32A boreholes, and will be performed as described in Appendix A of the FSP. Recovered soil samples from those boreholes will be logged and characterized as also described in Appendix A of the FSP.

These new wells will be constructed in accordance with the procedures specified in Appendix E of the FSP and in a manner similar to temporary bedrock piezometer PZ-07C. Specifically, once each boring is advanced to bedrock, a nominal 6-inch OD roller bit will be used to drill a socket 3 feet into the top of competent bedrock. A 4-inch diameter black steel casing will then be lowered to the bottom of the socket and grouted in place to the ground surface using neat cement grout via the tremie method. After allowing the grout to cure for a minimum of 12 hours, or as otherwise specified by the manufacturer, the borehole will be advanced 13 feet below the steel casing by continuously coring the bedrock using the bedrock drilling methods described in Appendix E of the FSP. Following bedrock coring, a nominal 3- to 4-inch OD roller bit will be used to ream the core hole to approximately 13 feet below the bottom of the steel casing. Each of the wells will be completed using an open-hole construction, with the bottom 3 feet serving as a sump at the bottom of the well. However, for monitoring well MW-08C only, if natural fractures are observed in the bottom 3 feet of the core, a sump will be constructed using a 3-foot section of stainless steel pipe, grouted in place. Such a sump, if required, will be installed by carefully pumping a volume of grout to the bottom of the core hole that is slightly greater than the volume of the annular space between the sump and core hole wall. Next, the sump and grout basket will be installed by pushing the sump through the grout to the bottom of the borehole. Water and any excess grout that enter the sump will then be promptly bailed or pumped from that sump. Monitoring wells MW-31C and MW-32C will remain open hole construction regardless of whether natural fractures are observed in the bottom 3 feet of the core. Schematics of the overburden and bedrock monitoring well design are provided as Figure B-1 of Appendix B.

2.4.4 Temporary Piezometer/Monitoring Well Survey and Development

Upon installation, the location of all new piezometers and monitoring wells will be surveyed and tied into the existing horizontal and vertical datum used for the Site. As requested by EPA, 14 monitoring wells in and adjacent to the Mill Street Area will be resurveyed as a check on the water level elevation data that is being used to develop overburden groundwater table and bedrock potentiometric surface contour maps in the quarterly Water Monitoring Reports submitted under the *Surface Water and Groundwater Monitoring Plan* (also known as the Water Monitoring Plan [WMP], ARCADIS, April 2008). Specifically, in addition to the survey of all new monitoring wells, piezometers, and pumping wells, the following existing monitoring wells will be resurveyed: MW-09A, MW-09B, MW-10A, MW-10B, MW-10C, MW-22A, MW-22B, MW-22C, MW-23A, MW-23B, MW-23C, MW-24A, MW-24B, and MW-24C. As part of these survey activities, reference points on the risers used for water level measurements will be clearly marked for future reference. Any differences between previous survey information for the existing wells will be documented in the final report documenting the activities specified in this Work Plan and/or in the following Water Monitoring Report (WMR).

The new wells and piezometers will also be developed in accordance with Appendix E of the FSP. Purge water generated during development will be managed as described in Section 6.

2.5 Baseline Water Quality Sampling and DNAPL Monitoring

Following the redevelopment of existing monitoring wells (as described in Section 2.2) and the installation and development of temporary piezometers/monitoring wells (as described in Section 2.4), a round of water quality samples will be collected from each well/piezometer in the monitoring network for the hydraulic testing activities to establish the baseline groundwater quality prior to initiation of the pumping tests. The baseline sampling of these wells/piezometers may be performed as part of the April 2012 quarterly monitoring activities performed under the WMP. However, because installation of monitoring wells MW-08C, MW-31C, MW-32A, MW-32B, and MW32C and temporary piezometers PZ-07B, PZ-07C, PZ-21A, and PZ-21B will likely not be completed prior to that event, the baseline groundwater quality samples from those particular wells/piezometers will be collected upon completion of the installation and development activities. Regardless of the timing, the samples from these wells/piezometers will be collected using the procedures specified in Appendix F of the FSP, entitled "Groundwater Purging and Sampling Procedures of

Monitoring Wells" and submitted for analyses of Target Compound List (TCL) volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), and manganese. Details regarding the baseline sampling for the pumping wells are provided in Section 2.7.

Upon completion of the water quality sampling described above, 17 wells/piezometers will be monitored for the potential presence of DNAPL. Specifically, the potential presence of DNAPL will be checked in monitoring wells MW-03A, MW-04C, MW-07A, MW-08C, MW-11C, MW-21C, MW-22C, MW-23A, MW-23C, MW-24A, MW-24C, MW-26A, MW-31C, MW-32A, and MW-32C, as well as temporary piezometers PZ-07C and PZ-21A through the use of an interface probe, a bottom-loading bailer, and a peristaltic pump. Such monitoring will be performed in accordance with the procedures specified for MW-21C in revised Appendix H of the FSP, entitled "Dense Non-Aqueous Phase Liquid (DNAPL)/Light Non-Aqueous Phase Liquid (LNAPL) Sampling Procedures." If DNAPL accumulates in a well/piezometer prior to the pumping tests, it will be removed and, if sufficient volume is recovered, sampled using the procedures included in revised Appendix H of the FSP.

2.6 Overburden and Bedrock Pumping Well Installation and Development

One overburden and one bedrock pumping well will be installed to support the performance of the hydraulic testing activities described in this Work Plan. Both wells will be installed approximately 15 feet northeast of the MW/PZ-21 monitoring well/piezometer cluster at the locations shown on Figure 2. This location is also approximately 55 feet west/northwest from MW-07A, 55 feet southeast from the MW-23 well cluster, and 70 feet southwest from the MW-24 well cluster. This location was selected for several reasons. First, this location is within one of the SPTC cells that contain a portion of excavation cell O (which is to be excavated to bedrock, approximately 22 feet below grade, as shown on Figure 2). Second, as this location is near bedrock monitoring well MW-21C (in which trace amounts of DNAPL have previously been documented), this location will provide a relatively conservative assessment of the groundwater quality that may be generated during the dewatering activities associated with implementation of the OU-1 soil remedy. Finally, this location is roughly in the middle of four existing/new piezometer/monitoring well clusters (i.e., MW/PZ-07, MW/PZ-21, MW-23, and MW-24), yet at different distances and directions from each cluster. The resulting piezometer/monitoring well network is optimal for quantifying the size, shape, position, and rate of change of the cone of depression formed by the pumping tests, making it possible to determine the key aquifer parameters. Additional details regarding the installation and development of the two pumping wells are provided in the following sections.

2.6.1 Overburden Pumping Well Installation

Overburden pumping well PW-1 will generally be installed using the procedures specified in Appendix A of the FSP, except as otherwise noted below. A schematic of the overburden pumping well design is provided as Figure B-2 in Appendix B.

- The borehole will be drilled through the overburden and 5 feet into the bedrock. Overburden drilling will be conducted using drive and wash drilling techniques and bedrock drilling will be conducted using a nominal 8-inch OD roller bit. Soil samples will be collected continuously and recovered samples will be logged and characterized as discussed in Appendix A of the FSP.

- Overburden pumping well PW-1 will be constructed using 6-inch diameter stainless steel casing with a 10-foot long, 0.030-inch slot, and continuous wire-wrapped screen. This screen slot size was determined based on review of grain size data generated during pre-design activities conducted at the Mill Street Area.

- This pumping well will also include a 5-foot long sump below the screen; the sump will be installed into the 5-foot deep bedrock socket to allow the water level at the well to be pumped down to the top of rock, if necessary.

- The bottom of the screen and top of the sump will be located approximately at the top of bedrock.

- The annulus around the sump will be filled with neat cement grout and the cement grout will be allowed to cure for a minimum of 12 hours (or the duration recommended by the manufacturer) prior to continuing with the remainder of the well installation. The annulus around the screen will be filled with Morie #1 (or equivalent) silica sand from the bottom of the screen to approximately 3 feet above the top of the screen. The remainder of the annulus will be filled with a 2-foot bentonite plug above the sand pack, and neat cement grout to ground surface.

- Upon completion of the well installation and development activities, a pressure transducer will be installed inside a 1-inch diameter drop tube installed inside the well. A second 1.5-inch diameter, open-ended drop tube will also be installed inside the well for DNAPL monitoring. The latter drop tube will have a minimum 0.20 inch slot size and will be suspended a minimum of 0.3 feet above the bottom of the well.

2.6.2 Bedrock Pumping Well Installation

Bedrock pumping well PW-2 will be installed adjacent to overburden pumping well PW-1. A schematic of the bedrock pumping well design is provided as Figure B-2 in Appendix B. Bedrock pumping well PW-2 will be installed using the same procedures as specified for overburden pumping well PW-1, except as follows:

- A bedrock socket will be drilled using a nominal 8-inch OD roller bit to a depth of 3 feet into bedrock.

- A permanent, 6-inch diameter black steel casing will be installed into the 3-foot deep bedrock socket and the annulus around the casing grouted using neat cement grout via the tremie method from the bottom of the casing to ground surface. The grout will be allowed to set for a minimum of 12 hours or as otherwise specified by the manufacturer.

- The borehole will be advanced to 20 feet below the casing using the bedrock coring methods described in Appendix E of the FSP.

- The core hole will then be reamed to 20 feet below the casing using a 6-inch nominal diameter roller bit, creating an open-hole pumping well.

- The bottom 5 feet of core will be examined for natural fractures. If no natural fractures are present, the bottom 5 feet of borehole will serve as an open-hole sump. If natural fractures are observed, a sump will be installed by carefully pumping a volume of grout into the bottom of the borehole that is equal to the volume of the borehole intended to comprise the sump. The grout will be allowed to set for a minimum of 12 hours (or as specified by the manufacturer), before using a 6-inch nominal roller bit to ream out the grout from the borehole. The purpose of this method is to fill any bedrock fractures with grout, while maintaining the full diameter of the borehole, thus allowing space for the installation of a pump, DNAPL drop tube (for DNAPL monitoring and removal, if any), and an additional drop tube for a water level transducer.

- Upon completion of the well installation and development activities, a pressure transducer will be installed inside a 1 inch diameter drop tube installed inside the well. A second 1.5-inch diameter, open-ended drop tube will also be installed inside the well for DNAPL monitoring. The latter drop tube will have a minimum 0.20 inch slot size and will be suspended a minimum of 0.3 feet above the bottom of the well.

2.6.3 Survey, Development, and DNAPL Monitoring of Pumping Wells

Similar to the new monitoring wells and temporary piezometers, the pumping wells will be surveyed after installation. The survey will be tied into the existing horizontal and vertical datum used for the Site.

Overburden pumping well PW-1 will be developed in cycles by surging with an appropriate surge block for approximately 10 to 30 minutes and pumping for 10 to 30 minutes at the maximum sustainable rate, depending on pump capacity and the ability to manage water. These cycles will be repeated until the visible turbidity of the pumping water has been reduced to the extent practicable, or a maximum total development period of two work days. Bedrock pumping well PW-2 will be developed using the same procedures except that the surge block and pumping cycles will be repeated until the visible turbidity of the pumping water has been reduced to the extent practicable, or a maximum total development period of one work day. The pressure transducers installed in the network of 42 monitoring locations described in Section 2.3 will continue to record water level data every five minutes throughout the pumping well development process. These data will provide a qualitative assessment of hydraulic responses during pumping well development.

Following pumping well installation and development and prior to each step-drawdown test (as described in Section 2.8), a 1.5-inch diameter PVC drop-tube, with the bottom 5-feet slotted (with no bottom cap), will be installed at the bottom of the pumping well. The bottom of the drop tube will be monitored for the presence of DNAPL using an interface probe, a bottom-loading bailer, and a peristaltic pump in accordance with the requirements of revised Appendix H of the FSP. DNAPL monitoring will also be performed periodically during the step-drawdown test. If any DNAPL accumulates in the well prior to or during the test, it will be removed as soon as practicable using the revised procedures included as Appendix H of the FSP.

2.7 Specific Capacity Testing

Specific capacity tests will be performed at all 11 existing monitoring wells described in Section 2.3 (i.e., MW-07A, MW-21C, MW-22A, MW-22B, MW-22C, MW-23A, MW-23B, MW-23C, MW-24A, MW-24B, and MW-24C). Specific capacity testing will also be performed at new temporary piezometers PZ-07B, PZ-07C, PZ-21A, and PZ-21B, which will be installed as discussed in Section 2.4. The specific capacity tests will be conducted as described in Appendix N of the FSP, entitled "Specific Capacity Testing Procedures." In general, the specific capacity testing will consist of the following activities:

- Testing will be conducted for a pumping period of approximately one hour at each tested well.

- During each test, the tested well will be pumped at a rate sufficient to achieve a minimum of two feet of drawdown, if practicable, depending on the pump capacity and the volume of water generated.

- Water levels will be manually measured periodically at the tested wells to provide backup data and a quality control check for the transducer measurements. Such periodic measurements will be measured every 30 seconds to 1 minute during the first several minutes of pumping, until the water level has stabilized. Once the water level has stabilized, manual water levels will be measured approximately every 1 to 5 minutes.

- Water levels will be allowed to recover for a minimum of 2 hours or to 95% recovery of the test-well drawdown (whichever is encountered first), prior to subsequent specific capacity testing within the same monitoring well/temporary piezometer cluster.

2.8 Pumping Tests

Upon completion of the specific capacity testing activities, two different types of pumping tests will be performed at each pumping well: step-drawdown tests and constant-rate pumping tests. Additional details regarding each of these pumping tests are provided in the following sections.

2.8.1 Step-Drawdown Tests

Two step-drawdown tests will be conducted on two separate days at new pumping wells PW-1 and PW-2 to help select an appropriate pumping rate for a longer-term, constant-rate pumping test at each well. Prior to each step-drawdown test, a 1.5-inch diameter PVC drop-tube, with the bottom 5-feet slotted (with no bottom cap), will be installed to the bottom of the pumping well (before installing the pump). As discussed in Section 2.6.3, DNAPL monitoring and removal (if present) will be performed periodically during the step-drawdown test via this drop tube. A second drop tube constructed using 1-inch diameter PVC with a 5-foot-long screen and a bottom cap will be installed in each pumping well to facilitate installation of a pressure transducer for measurement of water levels during the pumping test.

The pump installed in each pumping well will include a check valve at the top of the pump to prevent back-flow of water from the discharge pipe after the pumping period. The discharge line will be plumbed through an in-line totalizing flowmeter, and then into on-site storage containers (frac tanks), which will be situated at the general locations shown on Figure 2. The discharge line will also include a valved sampling port to allow the collection of baseline groundwater quality samples (i.e., samples of untreated water from the pumping wells) for laboratory analysis, as further described below.

The step-drawdown test will consist of four 1-hour steps. The pumping rates during the four steps at overburden pumping well PW-1 are expected to be approximately 20, 40, 60 and 80 gallons per minute (gpm), which would result in a total volume of pumped water of approximately 12,000 gallons. The pumping rates during the four steps at bedrock pumping well PW-2 are expected to be approximately 5, 10, 15 and 20 gpm, which would result in a total volume of pumped water of approximately 3,000 gallons. Each step-drawdown test will be conducted consistent with the new pumping test SOP (Appendix Y of the FSP, entitled "Pumping Test Standard Operating Procedures", which is included as Appendix C of this Work Plan).

During each pumping step, the pumping rate will be measured approximately every minute for the first 10 minutes, and then every 5 minutes for the remainder of the 1-hour pumping step, making adjustments as necessary to maintain as constant a pumping rate as practicable throughout each pumping step. The actual pumping rates used during the step-drawdown tests may also be modified based on the drawdown observed in the pumping wells during testing and to avoid pumping the well dry. In addition, baseline groundwater quality samples will be collected from the pumping wells after approximately three well volumes have been removed during the initial step of the step-drawdown test for each pumping well. Samples will be submitted for analysis of the constituents listed in Table 1.

As previously indicated, each pumping well will be equipped with a pressure transducer to automatically measure the water level during the step-drawdown test. Transducers will also continue to record water level data approximately every minute at the network of 42 monitoring locations described in Section 2.3 and will provide a basis to qualitatively assess the extent of hydraulic responses at surrounding monitoring wells/piezometers. Water level measurements will also be obtained periodically using an electronic water level indicator to provide backup data and a quality-control check regarding the transducer measurements. After the cessation of pumping, recovery data will be recorded until the pumping well has recovered to within 95% of the static water level. The water level and pumping-rate data will be analyzed to identify an appropriate, sustainable pumping rate to be used during the constant-rate pumping tests at pumping wells PW-1 and PW-2.

Near the end of each step-drawdown test, but before the termination of pumping, a sample of the discharge water will be collected from the sampling port in the discharge line for laboratory analysis of the constituents specified in Table 1. The data from the analysis of these samples will be utilized (along with similar samples collected during the constant-rate pumping tests) to verify the anticipated influent characteristics of dewatered liquids that will be generated during implementation of the OU-1 soil remedy and, if necessary, to modify the design of the temporary water treatment system for the remedy.

2.8.2 Constant-Rate Pumping Tests

All pumping wells, monitoring wells, and piezometers will be allowed to recover to 95% of their pre-step drawdown test water levels prior to beginning the first constant-rate pumping test at overburden pumping well PW-1. Similarly, all pumping wells, monitoring wells, and piezometers will be allowed to recover to 95% of the water levels observed prior to beginning the first constant-rate pumping test before initiating the second constant-rate pumping test at bedrock pumping well PW-2.

Similar to the step-drawdown tests, separate 8-hour constant-rate pumping tests will be conducted on two separate days at pumping wells PW-1 and PW-2, using the pumping rates identified based on the step-drawdown test results. The general equipment setup for each constant-rate pumping test will be the same as described above for the step-drawdown tests, including drop tubes, pump with check valve, and discharge line with flowmeter and sampling port.

Each constant-rate pumping test will be conducted using procedures similar to those implemented for the step-drawdown tests and will include the following additional activities:

- The pressure transducers installed in each pumping well will be programmed to record water levels throughout the constant-rate testing, starting immediately prior to the beginning of pumping, using a logarithmic data collection schedule with initial data collection at least once every 5 seconds, and decreasing frequency leading to a maximum interval of no greater than 5 minutes between measurements.

- Collection of static, pre-pumping water level measurements prior to the beginning of pumping. Collection of manual water level measurements periodically at select monitoring wells/temporary piezometers, and more frequent manual water level measurements at the pumped well and nearby monitoring wells/temporary piezometers to provide backup data and a quality-control check regarding the transducer measurements.

- Measurement of the pumping rate approximately every minute for the first 10 minutes, and on a regular basis throughout the remainder of the 8-hour pumping test, making adjustments as necessary to maintain as constant a pumping rate as practicable throughout the test.

- Collection of samples of pumped water from the sampling port in the discharge line after approximately 4 hours and 8 hours of pumping for laboratory analysis of the constituents specified in Table 1. The data from the analyses of these samples will be combined with the data from the step-drawdown tests to verify the anticipated influent characteristics of dewatered liquids that will be generated during implementation of the OU-1 soil remedy and, if necessary, to modify the design of the temporary water treatment system for the remedy.

- After the cessation of pumping, recovery data will be recorded until the pumping well and all monitoring wells/temporary piezometers (installed with transducers) have recovered to within 95% of the static water level. The recovery data will be measured at the same logarithmic schedule used during the constant-rate pumping period, with a maximum interval of five minutes. In addition, the recovery will be monitoring for a minimum of one week after pumping ceases.

2.9 Post-Hydraulic Testing Groundwater Quality Sampling and DNAPL Monitoring

Similar to the baseline groundwater quality sampling discussed in Section 2.5, a round of groundwater quality samples will be collected from each well/piezometer in the monitoring network for the hydraulic testing activities to establish the post-hydraulic testing groundwater quality. Those samples will be collected using the procedures specified in Appendix F of the FSP and submitted for analyses of TCL VOCs, PCBs, and manganese.

The groundwater sampling of these wells/piezometers may be performed as part of the July 2012 quarterly monitoring activities performed under the WMP.

Upon completion of the water quality sampling, monitoring wells MW-03A, MW-04C, MW-07A, MW-08C, MW-11C, MW-21C, MW-22C, MW-23A, MW-23C, MW-24A, MW-24C, MW-26A, MW-31C, MW-32A, and MW-32C, temporary piezometers PZ-07C and PZ-21A, and pumping wells PW-1 and PW-2 will be monitored for the potential presence of DNAPL through the use of both an interface probe, a bottom-loading bailer, and a peristaltic pump. Such monitoring will be performed in accordance with the procedures specified for monitoring well MW-21C in revised Appendix H of the FSP. If any accumulated DNAPL is observed in any of the wells/piezometers, it will be removed and, if sufficient volume is recovered, sampled using the procedures included in revised Appendix H of the FSP.

2.10 Data Analysis

The data from the specific capacity, step-drawdown and constant-rate tests will be analyzed using standard well hydraulics methods as summarized in Kruseman and de Ridder (1990) with assistance from applicable software (e.g., AqteSolv™ or similar). As previously indicated, the revised hydraulic conductivity estimates and drawdown responses observed during the testing will be used to update and re-calibrate the existing groundwater flow model. The revised groundwater flow model will then be used to run various simulations to refine the estimated dewatering rates that could be necessary during excavation dewatering at the Mill Street Area during implementation of the OU-1 soil remedy. Should the pumping test result in modifications to the estimated dewatering rates for the OU-1 soil remedy, appropriate modifications to the support of excavation design, dewatering design, and/or temporary water treatment system design, will be provided in the revised Final Design Report and Final Bid Documents as necessary. Such modifications could include the following:

- SPTC Wall – A pumping rate of less than 35 to 40 gpm (70 to 80 gpm after applying a factor of safety of two) could allow for the elimination of certain interior SPTC walls, which could result in a shorter implementation schedule as certain interior cell walls might be eliminated which could in turn result in greater excavation production rates associated with larger excavation cells. Further, a pumping rate less than 2 to 5 gpm (5 to 10 gpm after applying the factor of safety) could enable the potential use of alternate materials of construction in the support of excavation design (e.g., soldier piles and lagging, steel sheeting, secant pile wall, etc.). Conversely, a pumping rate greater than 90 gpm (180 gpm after applying the factor of safety) could require the construction of additional interior SPTC walls, further compartmentalizing the excavation cells which would result in additional time to construct the SPTC walls and lower excavation production rates, thereby adversely impacting the implementation schedule.

- Dewatering System – A pumping rate less than 75 gpm (150 gpm after applying the factor of safety) could potentially allow for fewer dewatering wells/well points and smaller pumps. Further, a pumping rate as low as 10 to 20 gpm (20 to 40 gpm after applying the factor of safety) could enable the use of sumps to dewater the excavations in lieu of dewatering wells/well points. Conversely, a pumping rate greater than 90 gpm (180 gpm after applying the factor of safety) could require additional dewatering wells/well points, additional piping, and/or larger pumps.

- Temporary Water Treatment System - A pumping rate less than 15 gpm (30 gpm after applying the factor of safety) could potentially allow for a smaller temporary water treatment system and/or less storage capacity (which would provide more space for other activities on a site that already has space restrictions) and the need for less maintenance during operation (due to a smaller volume of water requiring treatment). Pumping rates between 75 and 100 gpm (150 and 200 gpm after applying the factor of safety) could likely be handled with relatively minor upgrades (e.g., changing out pumps, adding filters, etc.) to the temporary water treatment system. However, a pumping rate greater than 100 gpm (200 gpm after applying the factor of safety) could require significant upgrades, a larger treatment system and/or additional storage capacity (on a site that already has space restrictions) and the need for increased maintenance during operation (due to a larger volume of water requiring treatment).

3. Pre-Construction Verification Sampling

The installation of vertical excavation supports will be required around certain excavation cells at the Elm Street Area where the depth of the bottoms of adjacent excavation cells differ by more than four feet in depth and sloping of excavation sidewalls is not proposed. The Final Design Report included a VSP which provided details regarding the sidewall and excavation bottom confirmation sampling procedures required to verify the achievement of the EPA-specified soil cleanup levels (SCLs) applicable to the Elm and Mill Street Areas. As indicated in Table A-3 and Figure A-18, the VSP includes the collection of 40[1] sidewall confirmation samples on the passive side of certain excavation supports at the Elm Street Area. These samples include 35 composite samples to be collected from 34 sampling locations and five grab samples from two sampling locations.

As discussed in EPA's December 2, 2011 letter to GE's counsel, the performance of sidewall confirmation sampling prior to implementation of the OU-1 soil remedy will "…allow for the sequencing, backfilling, and re-design of the excavation to ensure that the support wall is in the correct location and will not need to be moved during the remedial action which would be a large, timely, and expensive undertaking." Specifically, collection of the soil samples prior to implementation of the OU-1 soil remedy will significantly reduce the need to perform post-excavation confirmation sidewall sampling and the potential need to relocate excavation supports during construction (based on the results of such sampling), simplifying sequencing and reducing the schedule of the required excavation and backfilling activities at the Elm Street Area.

Table 2 presents a summary of the pre-construction verification soil samples that will be collected. This total includes the collection of 28 composite soil samples and five grab samples for analysis of PCBs from the locations shown on Figure 3. Eight of the composite soil samples specified on Table A-3 and shown on Figure A-18 of the Final Design Report will not be collected at this time due to the slope along the riverbank at the Elm Street Area and the resulting difficulty advancing these soil borings to the necessary depth to collect the samples. Those samples will be collected during implementation of the OU-1 soil remedy using the procedures specified in the VSP. The soil boring locations will be surveyed prior to sample collection to precisely document the location of the verification samples as they

[1] As proposed in Section 2.6 of the VSP, the scope of sidewall sampling requires the collection of one two-foot grab sample from each five-foot sampling horizon, as measured from the base of the shallower of two adjacent excavation cells. For excavation cells P3 and V, an additional pre-construction verification sample is proposed herein based on a difference of approximately 13 feet between the excavation bottoms (as opposed to a difference of eight feet as noted in Table A-3 of the VSP).

relate to the location of the required excavation supports (i.e., five feet from the location of the excavation supports).

The soil borings and sample collection activities will be performed using a direct push geoprobe and/or split-spoon sampling equipment in accordance with the procedures specified in Appendices A and O of the FSP. Upon completion of all drilling, each borehole will be sealed using tremie grout to grade with a cement-bentonite grout placed in the boreholes from the bottom of the boring to grade. Following laboratory analysis of the collected confirmation soil samples specified in the VSP and receipt of the sample data, the data will be evaluated using the procedures and against the criteria specified in the VSP. Should the verification sampling results require modification to the support of excavation design for the Elm Street Area, such modifications will be provided in the revised Final Design Report and Final Bid Documents, as necessary.

4. Soil Characterization for Off-Site Treatment/Disposal

The primary objective of the soil characterization is to provide sufficient data to facilitate: (1) characterization of the soils that will be excavated during implementation of the OU-1 soil remedy; and (2) preparation of profiles for approval by the receiving treatment and/or disposal facilities prior to the excavation of those soils (thereby streamlining the implementation of the OU-1 soil remedy). As indicated in Table 6 of the Final Design Report, approximately 27,000 in-situ cubic yards of material will be excavated during implementation of the OU-1 soil remedy, including approximately 17,000 cubic yards from the Elm Street Area and approximately 10,000 cubic yards from the Mill Street Area. Limited soil characterization data exists to characterize the soils subject to excavation. Specifically, analyses of soil samples collected during the pre-design investigation was generally limited to PCBs and those constituents in surface soils at the Elm and Mill Street Areas for which EPA had established SCLs (i.e., benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene and arsenic). Eleven (11) samples were collected during the pre-design investigation for analyses using the toxicity characteristic leaching procedure (TCLP), including: two samples of underground storage tank residuals at the Elm Street Area; five samples of specific paint or resin materials observed during test pitting activities at the Elm Street Area; and four samples of bulk soils excavated during the test pitting activities. Additional details regarding previous soil characterization sampling activities is provided below, along with details regarding the soil characterization activities described in this Work Plan.

As indicated in Table 14 of the Pre-Design Report dated January 14, 2005 and updated April 2, 2009 (Pre-Design Report) and Table 12 of the Final Design Report (subsequently revised in Tables 12A and 12B and submitted to EPA via electronic mail on May 12, 2009), nine of the 11 soil characterization samples collected during the pre-design investigation were submitted for full TCLP analyses, while the remaining two samples were submitted for only TCLP metals analysis. As also indicated therein, 10 of the 11 samples did not contain any constituents at concentrations greater than their corresponding TCLP regulatory limits. The lone exception, sample ESTP-3a-YP (3-3.5'), was a sample of yellow paint-like material observed during excavation of test pit #3 at the Elm Street Area, which contained both chromium and lead at levels above the TCLP regulatory limit of 5 milligrams per liter (mg/L). This test pit was excavated in the vicinity of monitoring well MW-03, which is also in the vicinity of the resinous mass observed by EPA during its remedial investigation. (As documented in the Pre-Design Report, this large mass of resinous material was not observed by GE contractors during the pre-design investigation activities.) The results of the soil characterization sampling will assist in developing profiles prior to initiation of the OU-1 soil remedy, thereby minimizing the downtime associated with stockpiling soils, awaiting laboratory analysis of soil characterization samples, and preparing and obtaining approval of profiles during remedy implementation.

The scope of the soil characterization sampling activities was developed based on several considerations including: (1) our understanding of the historic usage of the Elm and Mill Street Areas and the results of previous investigations at each area; (2) the scope of the soil boring activities associated with the pre-construction verification sampling activities at the Elm Street Area and the hydraulic testing at the Mill Street Area; and (3) the limits of excavation provided in the draft Final Design Report. Based on these considerations, 89 soil characterization samples will be collected, including: 39 samples at the Elm Street Area and 50 samples at the Mill Street Area. Additional details regarding the basis for and scope of the soil characterization sampling activities for the Elm and Mill Street Areas are provided below.

Elm Street Area

Based on the historic usage of the Elm Street Area, 20 of the soil characterization samples are surface/near-surface samples (i.e., top two feet below the sand cap/cover layer where present). Specifically, as illustrated on Figure 3, five of these samples (SC18, SC21, SC23, SC38 and SC39) will be collected within the footprint of the former warehouse, four of the samples (SC1 through SC4) will be collected within the northwest portion of the property that was formerly used for drum storage and the remainder of the surface/near-surface samples will be distributed throughout the Elm Street Area. In addition, 19 subsurface soil samples will be collected within/adjacent to certain of the deeper excavation cells at the Elm Street Area at the locations shown on Figure 3. Table 2 presents a summary of the soil characterization sampling activities for the Elm Street Area. As noted thereon, each sample will be submitted for analysis of PCBs and TCLP metals. Eight of those samples (approximately 20%) will also be submitted for analysis of TCLP VOCs, TCLP SVOCs, and TCLP pesticides/herbicides.

In addition to the soil characterization activities described above, to further delineate the volume of potential RCRA characteristic paint and resinous material that might be excavated at the Elm Street Area during implementation of the OU-1 soil remedy, a number of borings will be advanced in the vicinity of the MW-03 monitoring well cluster. Specifically, the soil borings at locations G-1, G-2, G-3, and G-4 for collection of sidewall verification samples will be installed and the sample cores visually inspected for the potential presence of paint and/or resinous material. The results of those visual inspections will be compared with the soil boring and test pit logs from the pre-design investigation to determine if additional borings are necessary to visually delineate the extent of paint and/or resinous material. Additional borings may be performed to the proposed depth of the excavation cells in this area to assist with the visual delineation of the paint and/or resinous material. Finally, depending on whether paint or resinous material is observed during these visual delineation activities, and, if so, the volume of such materials, it is anticipated that at least two to three additional samples will be collected of the paint or resinous materials for full TCLP analyses to assist with characterization of such materials prior to implementation of the OU-1 soil remedy.

Mill Street Area

The locations of the soil characterization sampling activities at the Mill Street Area are based on the historic usage of the area. Fifteen (15) surface/near-surface samples will be collected at the Mill Street Area, including five samples (SC51, SC55, SC58, SC60 and SC62) in the vicinity of the former storage shed. In addition, 35 subsurface soil samples will be collected within certain of the deeper excavation cells at the Mill Street Area at the locations shown on Figure 4. Table 2 presents a summary of the soil characterization sampling activities for the Mill Street Area. Based on the observance of elevated levels of VOCs in certain wells at/near the Mill Street Area during quarterly groundwater monitoring activities, each sample will be submitted for analysis of TCLP VOCs and PCBs. In addition, the five surface/near-surface soils samples collected in the vicinity of the former shed will also be submitted for TCLP metals analysis, and one of those will also be submitted for TCLP SVOC and TCLP pesticides/herbicides analysis. Finally, five of the subsurface soil samples (approximately 10% of the total number of Mill Street Area samples) will also be submitted for analysis of TCLP SVOCs, TCLP metals, and TCLP pesticides/herbicides.

All soil borings and sample collection activities for the Elm and Mill Street Areas will be performed using a direct push geoprobe and/or split-spoon sampling equipment in accordance with the procedures specified in Appendices A and O of the FSP. Prior to drilling, the sampling locations will also be surveyed to precisely document the location of each soil boring. To the extent possible, and as indicated in Table 2 and Figures 3 and 4, the sample locations will be co-located with the soil borings to install the pumping wells and temporary piezometers at the Mill Street Area (as described in Section 1) and to collect the sidewall verification soil samples at the Elm Street Area (as described in Section 2). The soil characterization sampling activities at the Mill Street Area will be completed prior to the initiation of the step-drawdown and constant-rate pump testing activities described in Section 1. Upon completion of all drilling, each borehole will be sealed using tremie grout to grade with a cement-bentonite grout placed in the boreholes from the bottom of the boring to grade. Following laboratory analysis of the collected soil characterization samples and receipt of the sample data, the data will be compared to the applicable TCLP regulatory limits. The results of that comparison will be used to estimate the potential volume of RCRA characteristic soils that will be excavated during implementation of the OU-1 soil remedy.

5. Equipment Cleaning/Disposal

As a precautionary measure, polyethylene sheeting or another type of barrier will be placed beneath vehicles driving onto/across the Elm and Mill Street Areas to eliminate the potential need for decontamination of the portions of the vehicles that might come into contact with Site soils. In addition, clean cover materials were placed over portions of both the Elm and Mill Street Areas during the remedial investigation and the subsequent demolition of the building at the Elm Street Area. In the event that any vehicles come into contact with Site soils, those vehicles will be cleaned in equipment decontamination areas that will be constructed at the Elm and Mill Street Areas. Such cleaning will consist of gross materials removal and wheel washing, if necessary.

In addition to any vehicle cleaning activities that may be necessary, personnel and equipment decontamination areas will be constructed at the Elm Street and Mill Street Areas. Any non-disposable equipment/materials that come into contact with site soils will be appropriately cleaned in accordance with the procedures specified in Appendix S of the FSP, entitled "Equipment Cleaning Procedures." Any remaining waste materials or disposable equipment generated during the supplemental design data collection activities will be containerized for proper off-site disposal at the end of the investigation.

6. Management of Investigation-Derived Waste (IDW)

The supplemental design data collection activities described herein will result in the generation of waste materials that will require management and treatment/disposal. Such materials will include soil/rock cuttings, groundwater, decontamination liquids, and miscellaneous waste materials (i.e., disposable equipment, personal protective equipment [PPE], plastic sheeting and other debris). The disposition of materials generated during the field activities will be in accordance with the *Site Management Plan* (SMP) which is Appendix I of the POP, and the most recent version of the Contingency Plan submitted to EPA on April 15, 2011 (which replaces Section 4 of the SMP).

Groundwater generated during the installation/development of the temporary piezometers and monitoring wells, the specific capacity tests, installation/development of pumping wells, step-drawdown pumping tests, constant-rate pumping tests, and equipment decontamination will be temporarily stored in frac tanks and treated on-site using a temporary water treatment system before discharge to the drainage ditch adjacent to the Mill Street Area (after verifying compliance with the discharge limits in the Final Design Report, as modified by EPA's September 29, 2011 approval with modifications). The timing of each discharge event will ultimately be dependent on the pumping rates for the constant-rate tests and the storage capacity of the on-site frac tanks. However, the following discharge sequence is currently anticipated:

- Water from the drilling activities, well development, specific capacity tests, and step-drawdown tests will be stored, and then treated and discharged to the drainage ditch prior to conducting the first constant-rate pumping test.

- Water levels from the transducers installed in monitoring wells near the drainage ditch (i.e., MW-08A, MW-08B, MW-08C, MW-09A, and MW-09B) will be evaluated to ensure that the water discharged to the drainage ditch has not discernably influenced water levels in nearby wells. If the surrounding wells have been influenced by the discharge, the constant-rate pumping tests will be delayed until the water levels return to static conditions prior to starting the first constant-rate pumping test.

- Ideally, water from the constant-rate pumping tests will be stored, and then treated and discharged as one event after all water levels have returned to 95% of the pre-pumping levels. However, if necessary based on storage capacity, water from the first constant-rate pumping test will be stored, treated and discharged to the drainage ditch prior to conducting the second constant-rate pumping test.

The frac tanks will be situated in the general area shown on Figure 2. The treated water will be sampled and analyzed for VOCs, SVOCs, PCBs, metals, and TSS prior to discharge. Table 3 provides the discharge limits for the temporary water treatment system presented in the *Final (100%) Design Report for the OSD Remedy*, as modified by EPA's September 30, 2011 comments (which incorporated comments from NHDES) and the constituent quantification limits.

With regard to solid waste such as the soil/rock cuttings, disposable sampling equipment, PPE, treatment process residuals, and other miscellaneous waste materials generated during the supplemental design data collection activities described herein, the results of EPA's remedial investigation, GE's pre-design investigation and the data collection activities described in this Work Plan will be utilized for waste characterization, supplemented as necessary by additional sampling.

7. Schedule and Reporting

It is anticipated that the drilling portion of the supplemental design data collection activities described herein could be initiated within two weeks of receipt of EPA approval of this Work Plan. Notification of the specific start date will be provided following receipt of EPA approval and scheduling of the mobilization date with the drilling subcontractor. It is anticipated that the field activities (excluding water and waste management) associated with the supplemental design data collection effort will have a duration of 90 days. To expedite the receipt, review, and evaluation of the supplemental design data, the collected sidewall verification and treated water samples will be submitted for a 14-day laboratory turnaround time. The pumping well and soil characterization samples will be submitted with standard turnaround times.

Upon completion of the field activities, ARCADIS will prepare and submit a report (including supporting documentation) summarizing the activities performed and data obtained during implementation of the Work Plan. Evaluations of the supplemental design data collected and the need for any appropriate revisions to Final Design Report will be provided in that document and also reflected in the Final Bid Documents. The Supplemental Design Data Collection Report will include the following information:

- A discussion of the field activities performed;
- A discussion of the data resulting from the specific capacity tests;
- A discussion of the data resulting from the pumping tests;
- A discussion of the results of the groundwater flow model update and re-calibration;
- A discussion of the results of the dewatering simulations;
- Water level data (both manual measurements and data loggers);
- A discussion of the verification sampling results;
- A discussion of the soil characterization results;
- A summary of the data validation activities for the verification soil sampling data (no other analytical results will be subject to data validation); and
- A conceptual site model reflecting subsurface and water chemistry data collected since submittal of the Pre-Design Report.

The Supplemental Design Data Collection Report will be supplemented by a number of tables, figures, and supporting information that summarize the data resulting from the investigation activities described in this Work Plan. Specifically, tables summarizing the following will be included in the report: soil sampling data; groundwater quality data; well construction data; and aquifer parameters. The report will also include the data curve plots for the different methods of aquifer parameter analysis. The report containing the information summarized above will be submitted to EPA approximately 90 days from completion of the field work (i.e., about 75 days from receipt of the final analytical data package).

Tables

TABLE 1
PUMPING TEST WATER SAMPLING

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

Sample Location	Sampling Frequency				Analysis (USEPA Method Number)
	Step-Drawdown Pumping Tests	Constant-Rate Pumping Tests		Treated Discharge	
	Near End of Test	At 4 hours	At 8 hours	One sample per filled frac tank	
PW-1 Effluent	X	X	X	--	PCBs (608), VOCs (624), SVOCs (625), Metals (200.7), TSS (2540D)
PW-2 Effluent	X	X	X	--	
Treated Water	--	--	--	X	

Notes:

1. Analysis of tert-amyl methyl ether (TAME), if required, will be by EPA Method 8260 rather than EPA Method 624.
2. Metals analyses include arsenic, cadmium, chromium, copper, iron, nickel and zinc and will be total metals, not dissolved.

TABLE 2
PRE-CONSTRUCTION VERIFICATION AND SOIL CHARACTERIZATION SAMPLING

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

Area	Excavation Cell ID	Proposed Pre-Construction Verification[5] and Soil Characterization Samples[6,7,8]						
		Sample ID	Sample Interval (Feet)	PCBs	TCLP Metals	TCLP VOCs	TCLP SVOCs and TCLP Pesticides/Herbicides	Corrosivity, Ignitability, Reactivity
Elm Street Area	A4/C	SC1	0-2[1]	X	X			
		SC2	0-2[1]	X	X			
		SC3	0-2[1]	X	X			
		SW-D3-D4	4-6	X				
			8-10	X				
		SW-D5-D6	4-6	X				
			8-10	X				
	D	SC4	0-2[1]	X	X			
		SC5	5-7	X	X	X	X	
	E1	SW-D1-D2	4-6	X				
			8-10	X				
	G	SC6	TBD[4]	X	X			
		SC7	TBD[4]	X	X	X	X	
		SC8	TBD[4]	X	X			
	H	SC9	0-2[1]	X	X			X
		SC10	0-2[1]	X	X			
		SC11[2]	1-3	X	X			
		SC12	0-2[1]	X	X			
		SW-G1-G2	7-9	X				
			12-14	X				
		SW-G3-G4	7-9	X				
			12-14	X				
		SW-K1-K2	7-9	X				
			11-13	X				
		SW-K3-K4	7-9	X				
			11-13	X				
		SW-Q3-Q4	7-9	X				
			12-14	X				
			17-19	X				
	J	SC13	0-2[1]	X	X			
		SC14	4-6	X	X	X	X	
	K	SC15	3-5	X	X			
		SC16	9-11	X	X			
	M	SC17	0-2[1]	X	X			
	P1	SC18	0-2[1]	X	X			
		SC19	5-7	X	X	X	X	
		SC20	6-8	X	X			
		SW-Q1-Q2	10-12	X				
			16-18	X				
		SW-Q6-Q7	10-12	X				
			16-18	X				
	P2	SC21	0-2[1]	X	X			
		SC22	5-7	X	X	X	X	
		SC23	0-2[1]	X	X			
	P3	SC24[3]	0-2[1]	X	X			
		SC25[3]	7-9	X	X			
		SW-V5-V6	14-16	X				
			19-21	X				
			22-24	X				
	Q	SC26	7-9	X	X			
		SC27	12-14	X	X	X	X	X
	R	SC28	0-2[1]	X	X			
		SW-Q5	11-13	X				
			14-16	X				
			18-20	X				
	S	SC29	0-2[1]	X	X			

TABLE 2
PRE-CONSTRUCTION VERIFICATION AND SOIL CHARACTERIZATION SAMPLING

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

Area	Excavation Cell ID	Proposed Pre-Construction Verification[5] and Soil Characterization Samples[6,7,8]						
		Sample ID	Sample Interval (Feet)	PCBs	TCLP Metals	TCLP VOCs	TCLP SVOCs and TCLP Pesticides/Herbicides	Corrosivity, Ignitability, Reactivity
Elm Street Area	T	SC30	0-2[1]	X	X			
		SC31	7-9	X	X			
		SW-V3-V4	18-20	X				
			21-23	X				
	U	SC32	0-2[1]	X	X			
	V	SC33	5-7	X	X			
		SC34	12-14	X	X	X	X	
		SC35	20-22	X	X			
	W	SC36	0-2[1]	X	X			
		SC37	3-5	X	X	X	X	
	Y	SW-V7	17-19	X				
			21-23	X				
	BB	SC38	0-2[1]	X	X			
		SC39	0-2[1]	X	X			
	DD	SW-Z1-Z2	6-8	X				
			11-13	X				
Mill Street Area	E	SC40	0-2[1]	X		X		
		SC41	4-6	X		X		
		SC42	7-9	X		X		
	H	SC43	0-2[1]	X	X	X		
		SC44	5-7	X		X		
		SC45	13-15	X	X	X	X	
		SC46	17-19	X		X		
		SC47	20-22	X		X		
	I	SC48	0-2[1]	X		X		
		SC49	3-5	X		X		
		SC50	7-9	X		X		
		SC51	0-2[1]	X	X	X		
		SC52	3-5	X		X		
		SC53	7-9	X		X		
	J	SC54	0-2[1]	X		X		
	K	SC55	0-2[1]	X	X	X		
		SC56	3-5	X		X		
		SC57	6-8	X		X		
	M	SC58	0-2[1]	X	X	X	X	X
		SC59	3-5	X		X		
		SC60	0-2[1]	X	X	X		
		SC61	3-5	X		X		
	O	SC62	0-2[1]	X	X	X		
		SC63	5-7	X		X		
		SC64	13-15	X	X	X	X	X
		SC65	17-19	X		X		
		SC66	20-22	X		X		
		SC67	0-2[1]	X		X		
		SC68	5-7	X		X		
		SC69	13-15	X		X		
		SC70	17-19	X		X		
		SC71	20-22	X	X	X	X	
		SC72	0-2[1]	X	X	X		
		SC73	5-7	X		X		
		SC74	13-15	X		X		
		SC75	17-19	X		X		
		SC76	20-22	X		X		
		SC77	0-2[1]	X		X		
		SC78	5-7	X		X		
		SC79	13-15	X	X	X	X	
		SC80	17-19	X		X		
		SC81	20-22	X		X		

TABLE 2
PRE-CONSTRUCTION VERIFICATION AND SOIL CHARACTERIZATION SAMPLING

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

Area	Excavation Cell ID	Proposed Pre-Construction Verification[5] and Soil Characterization Samples[6,7,8]						
		Sample ID	Sample Interval (Feet)	PCBs	TCLP Metals	TCLP VOCs	TCLP SVOCs and TCLP Pesticides/Herbicides	Corrosivity, Ignitability, Reactivity
Mill Street Area	R	SC82	0-2[1]	X		X		
		SC83	5-7	X	X	X	X	
		SC84	9-11	X		X		
		SC85	13-15	X		X		
	S	SC86	0-2[1]	X		X		
		SC87	3-5	X		X		
	T	SC88	0-2[1]	X		X		
		SC89	4-6	X		X		

Notes:
1. Surface/near-surface samples (0-2') will be collected from the top two feet of material located beneath any sand cap/cover materials, where present.
2. Soil characterization sample SC11 is a composite sample that will be collected from soil borings advanced in excavation cells H and R.
3. Soil characterization samples SC24 and SC25 are composite samples that will be collected from soil borings advanced in excavation cells P3 and Y.
4. This table excludes the soil characterization for any paint and/or resinous materials within the area of monitoring well cluster MW-03.
5. The sampling intervals for the pre-construction verification samples listed above have been modified from those listed in Table A-3 of the VSP. The sampling intervals listed above reflect depth from existing grade (as opposed to depth from the base of the excavation bottom on the passive side of the excavation support, as indicated in Table A-3) because these samples will be collected as part of the pre-construction supplemental design data collection activities.
6. With the exception of pre-construction verification sample locations SW-Q5 and SW-V7, all PCB samples are composite samples as noted in this table.
7. Certain soil characterization samples at the Elm Street Area (e.g., SC3, SC9 - SC11, SC20, SC24, SC25, SC30 and SC31) will be composited from soil borings advanced for pre-construction verification sampling.
8. At the Mill Street Area, soil characterization samples SC62 - SC66 will be composited from soil borings advanced to install temporary piezometers PZ-21A and PZ-21B; soil characterization samples SC82 - SC85 will be composited from soil borings advanced to install temporary piezometers PZ-07B and PZ-07C; and soil characterization samples SC67 - SC71 will be composited from soil borings advanced to install temporary pumping wells PW-1 and PW-2. Grab samples for analysis of TCLP VOCs will be collected from each soil boring at each specified depth interval, while the remaining samples for all other TCLP analyses will be composited from each boring.

TABLE 3
TEMPORARY WATER TREATMENT SYSTEM DISCHARGE CRITERIA AND CONSTITUENT QUANTIFICATION LIMITS

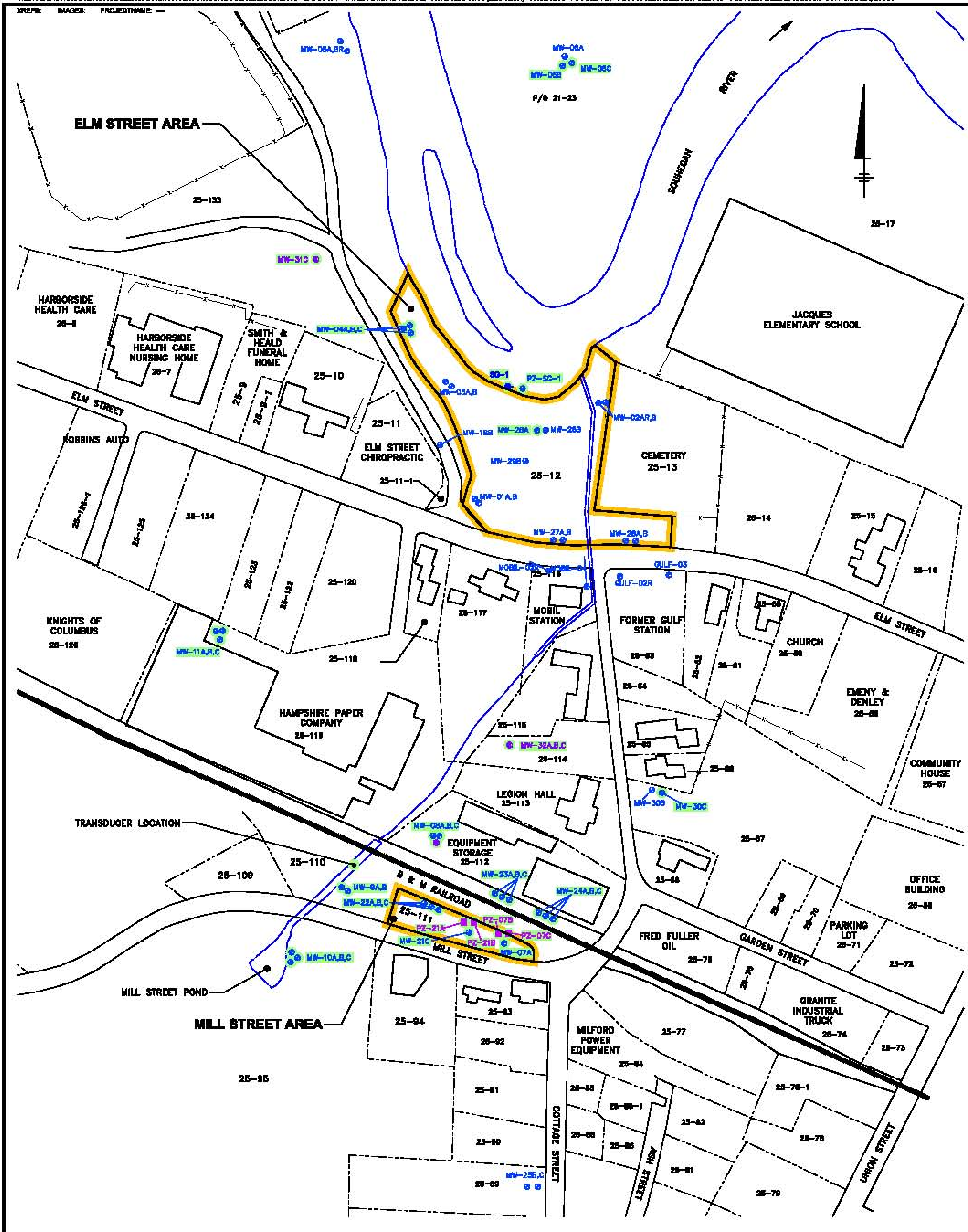
FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

Parameter	Limits of Quantification	Discharge Limits	Units	Limit Type Based on Monthly Sample	Sample Type
Total Suspended Solids	4	30	mg/L	Monthly Average	Grab
Benzene	5	5	ug/L	Daily Maximum	Grab
Toluene	5	Limited as Total BTEX		Daily Maximum	Grab
Ethylbenzene	5	Limited as Total BTEX		Daily Maximum	Grab
Xylenes,Total	10	Limited as Total BTEX		Daily Maximum	Grab
Total BTEX	10	100	ug/L	Daily Maximum	Grab
Methyl-tert-butyl ether (MTBE)	5	70	ug/L	Daily Maximum	Grab
tert-Butyl Alcohol (TBA)	20[3]	Monitor Only		Daily Maximum	Grab
tert-Amyl Methyl Ether (TAME)	1[3]	Monitor Only		Daily Maximum	Grab
1,4-Dichlorobenzene	5	5	ug/L	Daily Maximum	Grab
1,2-Dichlorobenzene	5	600	ug/L	Daily Maximum	Grab
1,3-Dichlorobenzene	5	320	ug/L	Daily Maximum	Grab
Total Dichlorobenzene	15	763	ug/L	Daily Maximum	Grab
1,2-Dichloroethane	5	5	ug/L	Daily Maximum	Grab
cis-1,2-Dichloroethene	5	70	ug/L	Daily Maximum	Grab
Trichloroethene	5	5	ug/L	Daily Maximum	Grab
Vinyl Chloride	5[4]	2	ug/L	Daily Maximum	Grab
Acetone	25	Monitor Only		Daily Maximum	Grab
Phenol, Total	5	300	ug/L	Daily Maximum	Grab
Bis(2-ethylhexyl)phthalate	10[5]	6	ug/L	Daily Maximum	Grab
Total Phthalates (Phthalate esters)	25[6]	3	ug/L	Monthly Average	Grab
Total Group II Polycyclic Aromatic Hydrocarbons (PAH)	80	100	ug/L	Daily Maximum	Grab
Fluorene	5	Limited as Total Group II PAH		Daily Maximum	Grab
Naphthalene	5	20	ug/L	Daily Maximum	Grab
Phenanthrene	5	Limited as Total Group II PAH		Daily Maximum	Grab
Total PCBs	0.065[7]	0.5	ug/L	Daily Maximum	Grab
Arsenic, Total	10	10[8]	ug/L	Monthly Average	Grab
Cadmium, Total	1	1.8[8]	ug/L	Monthly Average	Grab
Chromium, Total	4	43[8]	ug/L	Monthly Average	Grab
Copper, Total	10[9]	5.1[8]	ug/L	Monthly Average	Grab
Nickel, Total	10	30[8]	ug/L	Monthly Average	Grab
Zinc, Total	10	67[8]	ug/L	Monthly Average	Grab
Iron, Total	50	1,000[8]	ug/L	Daily Maximum	Grab

<u>Notes:</u>

1. The discharge limits provided above are based on the *Remediation General Permit (RGP) under the National Pollutant Discharge Elimination System (NPDES) for Discharges in New Hampshire.*
2. ug/L = Micrograms per liter; mg/L = milligrams per liter.
3. Analysis of tert-amyl methyl ether (TAME) and tert-butyl alcohol (TBA), if required, will be by EPA Method 8260 rather than EPA Method 624. As a result, the listed limits of quantification are for EPA Method 8260B.
4. Test America's method detection limit for vinyl chloride under EPA Method 624 is 1 ug/L. However, for compliance purposes a discharge limit should not be specified that is below the pratical quantitation limit of a Clean Water Act approved method.
5. Test America's method detection limit for bis(2-ethylhexyl)phthalate under EPA Method 625 is 0.86 ug/L. However, for compliance purposes a discharge limit should not be specified that is below the pratical quantitation limit of a Clean Water Act approved method.
6. Total phthalates is represents the sum of butylbenzyl phthalate, diethyl phthalate, dimethyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate. Test America's method detection limit for these constituents under EPA Method 625 are 1.3 ug/L, 0.17 ug/L, 0.16 ug/L, 0.93 ug/L, and 4.4 ug/L, respectively. However, for compliance purposes a discharge limit should not be specified that is below the pratical quantitation limit of a Clean Water Act approved method.
7. The total PCBs discharge limit is 0.000064 ug/L but the compliance limit is equal to the Minimum Level (ML) of the test method used (0.5 ug/L for EPA Method 608). The published method detection limit is 0.065 ug/L.
8. Discharge limits for cadmium, chromium, copper, nickel and zinc are hardness dependent; a site-specific hardness value of 52 mg/L as CaCO3 was assumed in the calculations.
9. Test America's method detection limit for copper under EPA Method 200.7 is 1.6 ug/L. However, for compliance purposes a discharge limit should not be specified that is below the pratical quantitation limit of a Clean Water Act approved method.

Figures



DRAFT
FOR EPA REVIEW

GRAPHIC SCALE

LEGEND:

- FENCE
- WATER
- RAILROAD
- PROPERTY LINES
- MONITORING WELL
- PROPOSED TRANSDUCER LOCATION
- PROPOSED MONITORING WELL
- PROPOSED PIEZOMETER LOCATION

NOTES:

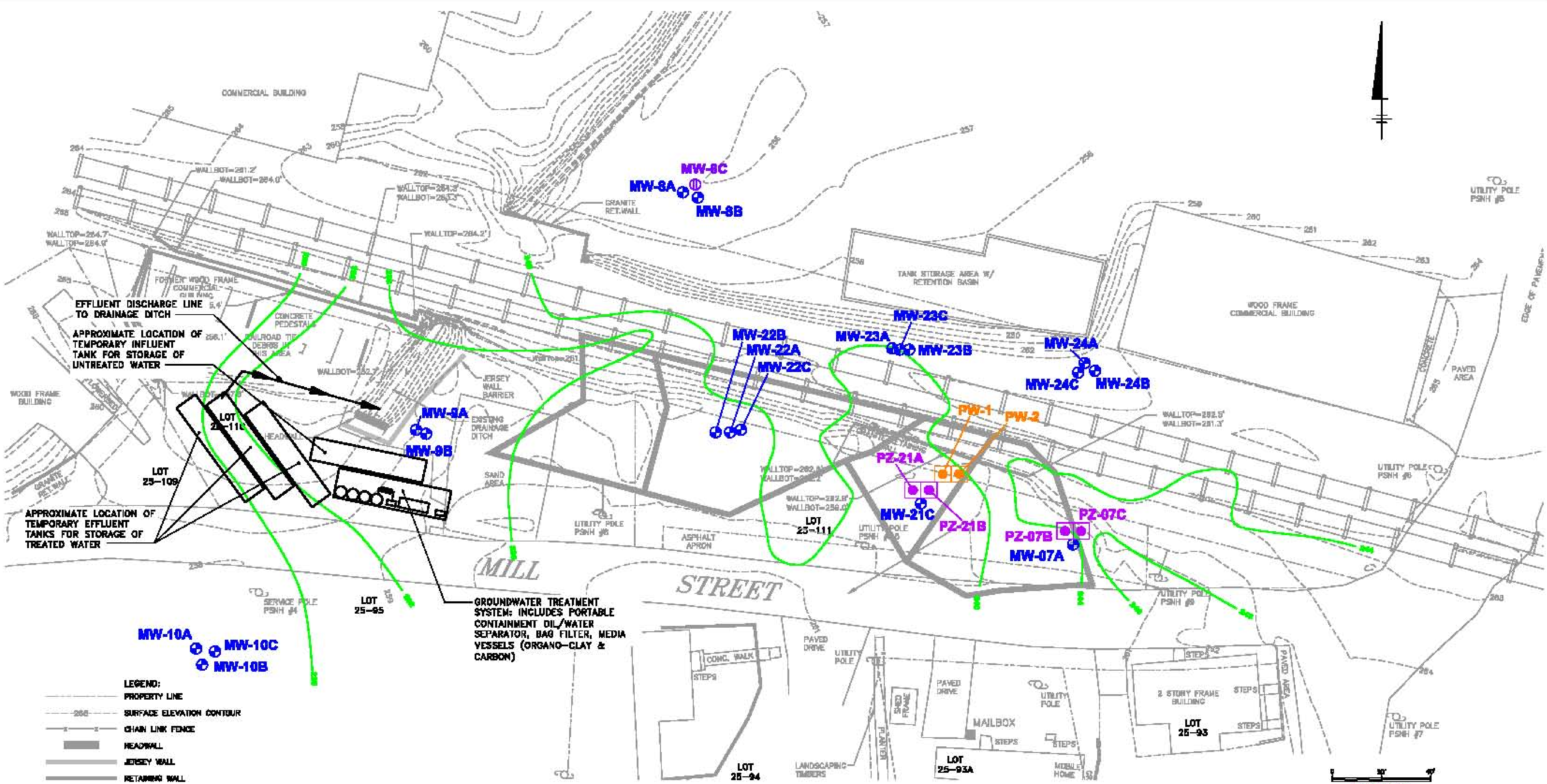
1. BASE MAP FEATURES (PROPERTY LINES, ROADS, AND RAILROAD) BASED ON TAX MAP NUMBER 26 FROM MERIDIAN LAND SERVICES, INC. DATED APRIL 1999.
2. BASE MAP FEATURES (BUILDINGS, RIVER) BASED ON PLATE 1 AND PLATE 2 FROM THE REMEDIAL INVESTIGATION REPORT (ARTHUR D. LITTLE, 1994).
3. ALL LOCATIONS ARE APPROXIMATE.
4. TRANSDUCERS WILL ALSO BE PLACED IN PUMPING WELLS PW-1 AND PW-2 AT THE MILL STREET AREA. SEE FIGURE 2 FOR LOCATION OF PUMPING WELLS.

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE - MILFORD, NEW HAMPSHIRE

TRANSDUCER LOCATIONS FOR HYDRAULIC TESTING

ARCADIS

FIGURE 1



LEGEND:

- PROPERTY LINE
- SURFACE ELEVATION CONTOUR
- CHAIN LINK FENCE
- HEADWALL
- JERSEY WALL
- RETAINING WALL
- GRANITE RETAINING WALL
- ASPHALT APRON INSTALLED DURING REMEDIAL ACTION PERFORMED IN 1995
- RETENTION BASIN
- PROPOSED APPROXIMATE LOCATION OF SOLDIER PILE AND TREMIE CONCRETE (SPTC) WALLS
- TOP OF BEDROCK ELEVATION CONTOUR IN FEET (SEE NOTE 2 ON SHEET DW-2 OF THE FINAL (100%) DESIGN REPORT)
- EXISTING MONITORING WELL
- NEW MONITORING WELL
- OVERBURDEN OR BEDROCK PUMPING WELL LOCATION
- OVERBURDEN OR BEDROCK TEMPORARY PIEZOMETER LOCATION

NOTES:

1. ELEVATIONS BASED ON NORTH AMERICAN VERTICAL DATUM OF 1988.
2. HORIZONTAL DATUM BASED ON NEW HAMPSHIRE STATE PLANE COORDINATE SYSTEM OF 1983.
3. CONTOUR INTERVAL = 1 FOOT.
4. MAP COMPILED FROM ACTUAL FIELD SURVEY PERFORMED BY EBL, INC. FROM JULY 18, 2003 THROUGH AUGUST 14, 2003, AND FROM MERIDAN LAND SERVICES, INC. ON JANUARY 22, 2004, AND BY ARCADIS ON MAY 24, 2007.
5. MILL STREET SITE PROPERTY LINE SHOWN WAS ESTABLISHED FROM DEEDS OF RECORD, SURVEY, AND EXISTING MONUMENTATION. OTHER PROPERTY LINES SHOWN WERE OBTAINED FROM TOWN OF MILFORD TAX MAP 25.
6. LOCATION OF UNDERGROUND UTILITIES AND OTHER UNDERGROUND STRUCTURES OBTAINED BY FIELD MEASUREMENTS WHERE POSSIBLE. LOCATION OF WATER, SEWER, AND DRAINAGE UTILITIES OBTAINED FROM TOWN OF MILFORD DEPARTMENT OF PUBLIC WORKS RECORDS.

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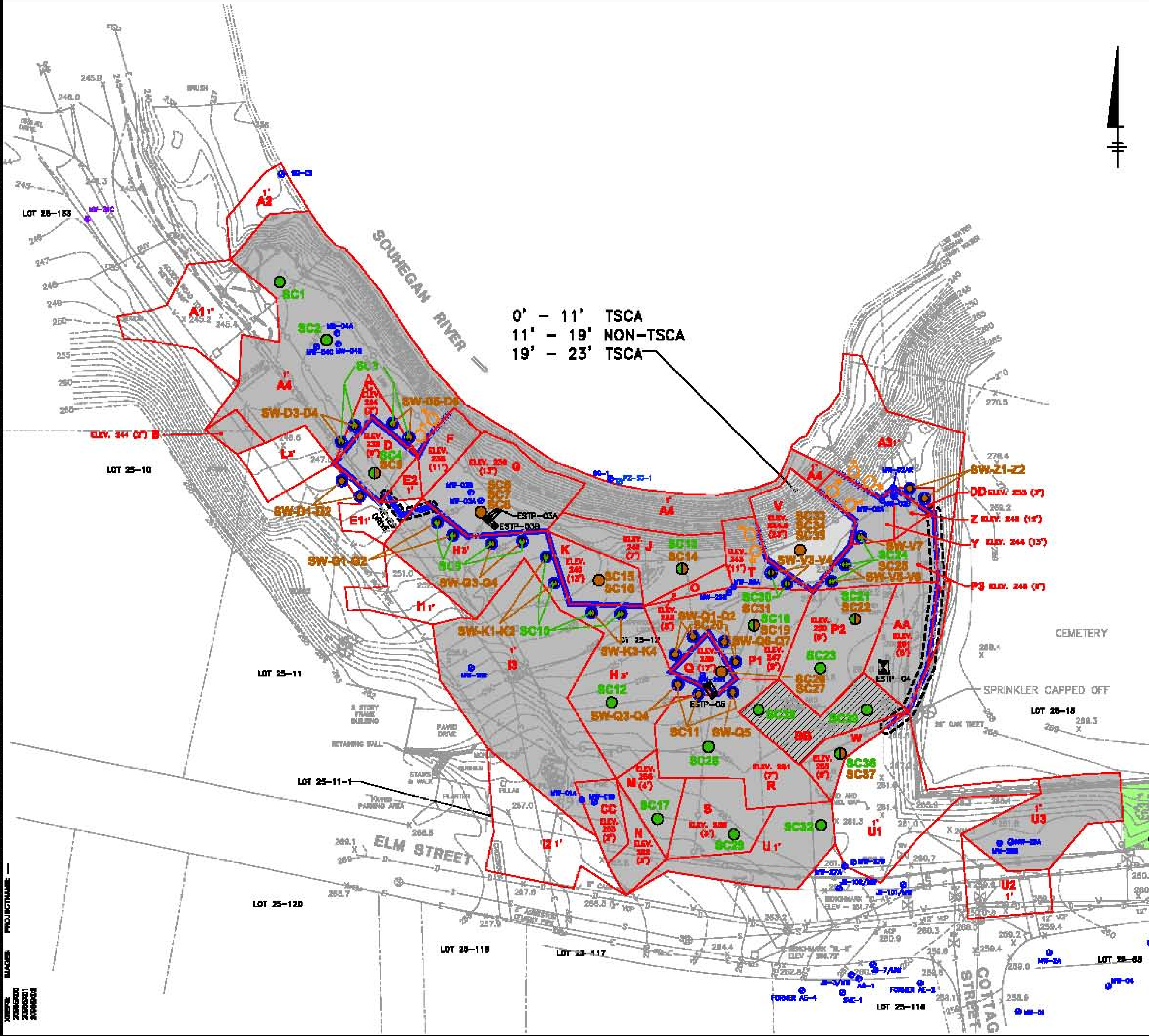
FOR EPA REVIEW

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE - MILFORD, NEW HAMPSHIRE

MILL STREET AREA - PUMPING WELL/ TEMPORARY PIEZOMETER LOCATIONS

ARCADIS

FIGURE 2



LEGEND FOR PRE-DESIGN INVESTIGATION AREA

- PROPERTY LINE
- UTILITY POLE
- CATCH BASIN
- SANITARY MANHOLE
- STORM MANHOLE
- WATER VALVE
- WATER METER
- TELEPHONE JACK
- INDEX SURFACE ELEVATION CONTOUR
- INTERMEDIATE SURFACE ELEVATION CONTOUR
- CHAIN LINK FENCE
- FIRE HYDRANT
- SG-1 STAFF GAUGE
- MW-08A EXISTING MONITORING WELL
- MW-31C PROPOSED MONITORING WELL
- SIDEWALL VERIFICATION BORING
- FUTURE SIDEWALL VERIFICATION BORING
- APPROXIMATE SURFACE/NEAR SURFACE SOIL CHARACTERIZATION SAMPLE LOCATION
- APPROXIMATE SUBSURFACE SOIL CHARACTERIZATION SAMPLE LOCATION
- APPROXIMATE SURFACE/NEAR SURFACE AND SUBSURFACE SOIL CHARACTERIZATION SAMPLE LOCATION
- PREVIOUS TEST PIT LOCATION
- APPROXIMATE ELEVATION OF 100-YEAR FLOOD PLAIN
- EXCAVATION LIMITS
- ELEV. 256 (4') BOTTOM OF EXCAVATION ELEVATION (DEPTH SHOWN IN PARENTHESES REPRESENTS GENERAL EXCAVATION DEPTH AND IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY)
- 4' DEPTH OF EXCAVATION
- AA EXCAVATION CELL ID
- EXCAVATION IN THIS AREA TO BE SLOPED FROM CELLS R AND W TO CELLS P2 AND AA
- LIMITS OF NON-TSCA MATERIAL
- LIMITS OF TSCA MATERIAL
- LIMITS OF NON-TSCA AND TSCA MATERIAL
- SOLDIER PILE AND LAGGING SUPPORT
- INDICATES EXCAVATION SIDEWALL NOT SUBJECT TO CONFIRMATORY SAMPLING

LEGEND FOR HISTORIC SOIL REMEDIATION AREA

- SS-1 ESE GRAB SAMPLE LOCATION
- PRIOR 1-FOOT REMOVAL

NOTES:

1. ELEVATIONS BASED ON NORTH AMERICAN VERTICAL DATUM OF 1988.
2. HORIZONTAL DATUM BASED ON NEW HAMPSHIRE STATE PLANE COORDINATE SYSTEM OF 1983.
3. CONTOUR INTERVAL = 1 FEET.
4. MAP COMPILED FROM ACTUAL FIELD SURVEY PERFORMED BY BSL, INC. FROM JULY 16, 2003 THROUGH AUGUST 14, 2003, BY MERIDAN LAND SERVICES, INC. JANUARY 22, 2004, AND BY ARCADIS ON MAY 24, 2007.
5. A SAND AND GRAVEL CAP WAS PREVIOUSLY INSTALLED OVER THE MAJORITY OF THE ELM STREET AREA BY USEPA. DURING THE PDI, THE CAP WAS OBSERVED TO BE APPROXIMATELY ONE FOOT THICK AT MOST LOCATIONS ACROSS THE PROPERTY. AT OTHER LOCATIONS, APPROXIMATE CAP THICKNESSES WERE MEASURED AS FOLLOWS: 1.5 FEET AT ES-156E, G06, M12, N18, O16, Q10, Q12E, Q16N, Q18, AND S14; TWO FEET AT O14, Q18, AND Q12; FOUR FEET AT M16; FIVE FEET AT S18; AND UP TO SIX FEET ALONG THE CEMETERY WALL AS MEASURED AT P18E. THE SAND AND GRAVEL CAP WILL BE REMOVED DURING THE SITE PREPARATION PHASE.
6. EXCAVATION CELLS WITH NO ELEVATION REFERENCE SHALL BE EXCAVATED TO THE DESIGNATED DEPTH AS MEASURED FROM GROUND SURFACE OR THE GEOTEXTILE LAYER (IF WITHIN THE SAND CAP).
7. ELM STREET SITE PROPERTY LINE SHOWN WAS ESTABLISHED FROM DEEDS OF RECORD, SURVEY, AND EXISTING MONUMENTATION. OTHER PROPERTY LINES SHOWN WERE OBTAINED FROM TOWN OF MILFORD TAX MAP 25.
8. REFER TO FIGURE 14 OF THE FINAL DESIGN REPORT FOR WELLS TO BE DECOMMISSIONED/PROTECTED DURING IMPLEMENTATION OF REMEDIAL ACTION AND NEW WELLS TO BE INSTALLED FOLLOWING PERFORMANCE OF THE REMEDIAL ACTION.

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0 30' 60'
GRAPHIC SCALE

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE - MILFORD, NEW HAMPSHIRE

ELM STREET AREA - PRE-CONSTRUCTION VERIFICATION AND SOIL CHARACTERIZATION SAMPLING

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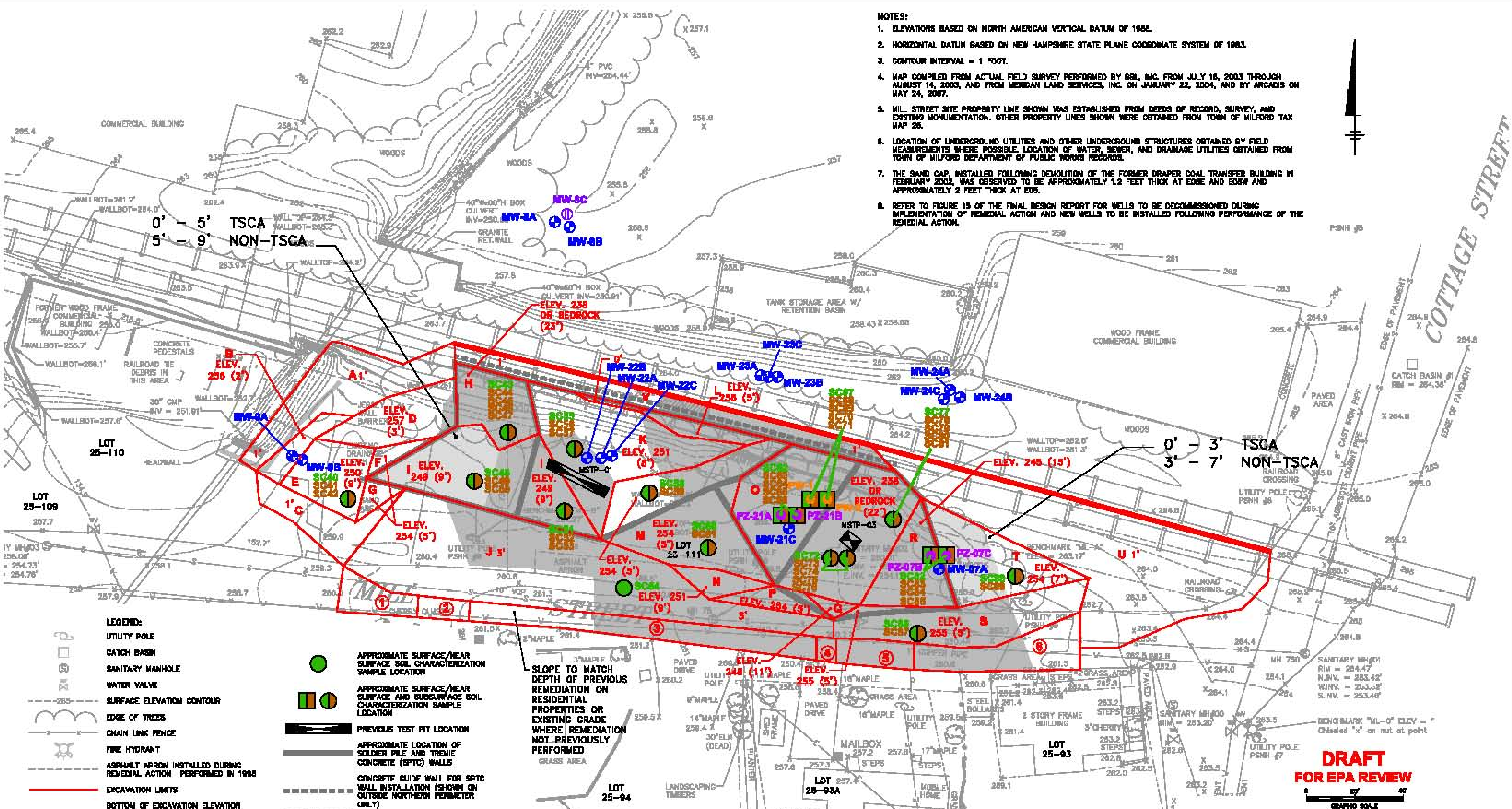
FIGURE 3

NOTES:

1. ELEVATIONS BASED ON NORTH AMERICAN VERTICAL DATUM OF 1988.
2. HORIZONTAL DATUM BASED ON NEW HAMPSHIRE STATE PLANE COORDINATE SYSTEM OF 1983.
3. CONTOUR INTERVAL = 1 FOOT.
4. MAP COMPILED FROM ACTUAL FIELD SURVEY PERFORMED BY SSL, INC. FROM JULY 16, 2003 THROUGH AUGUST 14, 2003, AND FROM MERIDAN LAND SERVICES, INC. ON JANUARY 22, 2004, AND BY ARCADIS ON MAY 24, 2007.
5. MILL STREET SITE PROPERTY LINE SHOWN WAS ESTABLISHED FROM DEEDS OF RECORD, SURVEY, AND EXISTING MONUMENTATION. OTHER PROPERTY LINES SHOWN WERE OBTAINED FROM TOWN OF MILFORD TAX MAP 26.
6. LOCATION OF UNDERGROUND UTILITIES AND OTHER UNDERGROUND STRUCTURES OBTAINED BY FIELD MEASUREMENTS WHERE POSSIBLE. LOCATION OF WATER, SEWER, AND DRAINAGE UTILITIES OBTAINED FROM TOWN OF MILFORD DEPARTMENT OF PUBLIC WORKS RECORDS.
7. THE SAND CAP, INSTALLED FOLLOWING DEMOLITION OF THE FORMER DRAPER COAL TRANSFER BUILDING IN FEBRUARY 2002, WAS OBSERVED TO BE APPROXIMATELY 1.2 FEET THICK AT E06E AND E06W AND APPROXIMATELY 2 FEET THICK AT E05.
8. REFER TO FIGURE 15 OF THE FINAL DESIGN REPORT FOR WELLS TO BE DECOMMISSIONED DURING IMPLEMENTATION OF REMEDIAL ACTION AND NEW WELLS TO BE INSTALLED FOLLOWING PERFORMANCE OF THE REMEDIAL ACTION.



LEGEND:

UTILITY POLE
CATCH BASIN
SANITARY MANHOLE
WATER VALVE
SURFACE ELEVATION CONTOUR
EDGE OF TREES
CHAIN LINK FENCE
FIRE HYDRANT
ASPHALT APRON INSTALLED DURING REMEDIAL ACTION PERFORMED IN 1998
EXCAVATION LIMITS
ELEV. 254 (5') BOTTOM OF EXCAVATION ELEVATION (DEPTH SHOWN IN PARENTHESES REPRESENTS GENERAL EXCAVATION DEPTH AND IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY)
3' DEPTH OF EXCAVATION
A EXCAVATION ID
EXISTING MONITORING WELL
NEW MONITORING WELL
OVERBURDEN AND BEDROCK PUMPING WELL LOCATION
OVERBURDEN AND/OR BEDROCK TEMPORARY PIEZOMETER LOCATION
APPROXIMATE SURFACE/NEAR SURFACE SOIL CHARACTERIZATION SAMPLE LOCATION
APPROXIMATE SURFACE/NEAR SURFACE AND SUBSURFACE SOIL CHARACTERIZATION SAMPLE LOCATION
PREVIOUS TEST PIT LOCATION
APPROXIMATE LOCATION OF SOLDIER PILE AND TREMIE CONCRETE (SPTC) WALLS
CONCRETE GUIDE WALL FOR SPTC WALL INSTALLATION (SHOWN ON OUTSIDE NORTHERN PERIMETER ONLY)
FOCUSED EXCAVATION
INDICATES A 1 FOOT VERTICAL 1.5 FOOT HORIZONTAL SLOPE
PROPERTY LINE
LIMITS OF NON-TSCA MATERIAL
LIMITS OF TSCA MATERIAL
LIMITS OF NON-TSCA AND TSCA MATERIAL

EXCAVATION CELL	DEPTH OF EXCAVATION (NORTH SIDE)	DEPTH OF EXCAVATION (SOUTH SIDE)
1	3'	0'
2	3'	1.25'
3	3'	1'
4	3' OR 6'	2'
5	6'	3'
6	6'	1'

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GRAPHIC SCALE

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE - MILFORD, NEW HAMPSHIRE

MILL STREET AREA - SOIL CHARACTERIZATION SAMPLING

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FIGURE 4

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Appendices

Appendix A

Schedule for Hydraulic Testing Program

TABLE A-1
SCHEDULE FOR HYDRAULIC TESTING PROGRAM

FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

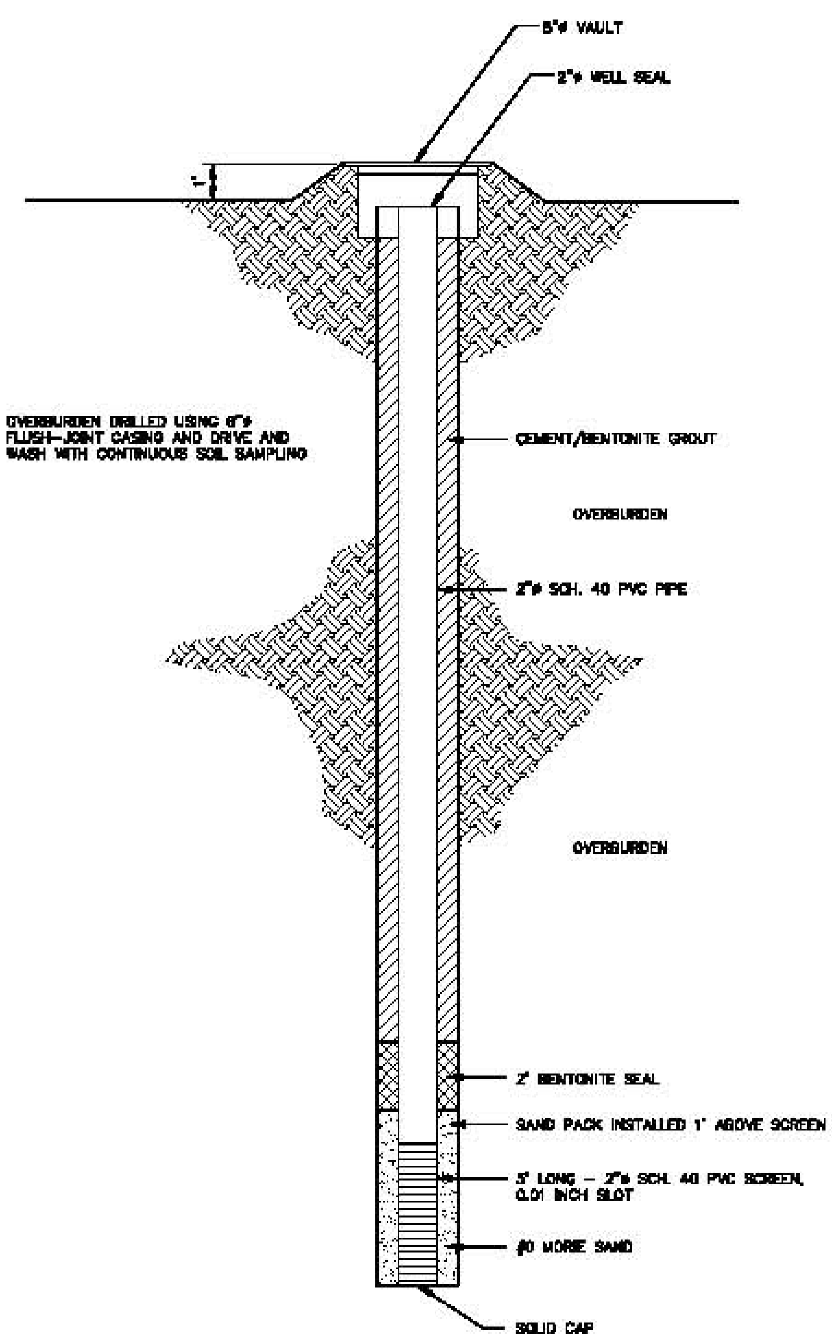
Activity	Details	Anticipated Duration (Work Days)[1]
Monitoring Well Redevelopment and Transducer Installation	The following monitoring wells will be redeveloped: MW-07A, MW-21C, MW-22A/B/C, MW-23A/B/C, and MW-24A/B/C	2 weeks
	Transducers will be installed at the following existing locations: MW-04A/B/C, MW-06B/C, MW-07A, MW-08A/B, MW-09A/B, MW-10A/B/C, MW-11A/B/C, MW-21C, MW-22A/B/C, MW-23A/B/C, MW-24A/B/C, MW-26A, MW-30C, staff gauge SG-1, and the box culvert where the drainage ditch passes under the railroad.	
Monitoring Well/Piezometer Installation, Development, Deploy Transducers in New Wells	The following wells/piezometers will be installed and developed: MW-08C, MW-31C, MW-32A/B/C, PW-1, PW-2, PZ-07B/C, and PZ-21A/B. Transducers will be installed in each of the above-listed wells/piezometers, as well as a temporary piezometer pushed into the riverbed next to staff gauge SG-1.	6 weeks
Specific Capacity Testing	Specific Capacity Testing will be performed at the following monitoring wells/piezometers: MW-07A, MW-21C, MW-22A/B/C, MW-23A/B/C, MW-24A/B/C, PZ-7B, PZ-7C, PZ-21A, and PZ-21B.	2 weeks
Step-Drawdown Testing	Step-drawdown testing will be performed at PW-1 and then PW-2. Testing will be conducted on two separate days with at least one day of recovery after each test.	1 week
1st Discharge of Treated Water	Treated water from drilling activities, well development, specific-capacity testing, and step-drawdown testing will be discharged to the ditch after the step-drawdown testing at PW-1 and PW-2 and after receiving the data from samples of the treated water.	1 day[2]
Constant Rate Pumping Test – PW-1 (overburden)	Constant rate test at PW-1 will commence approximately one week after the first discharge of treated water to the ditch to allow water levels to recover from the step tests, allow for potential hydraulic influence from the discharged water to dissipate, and to allow for evaluation of background water level trends prior to starting the first constant rate test.	1 day pumping and 1 week of recovery
Constant Rate Pumping Test – PW-2 (bedrock)	Constant rate test at PW-2 will commence approximately one week after the constant rate test at PW-1 to allow water levels to recover from the first test and to allow for evaluation of background water level trends.	1 day pumping and 1 week recovery
2nd Discharge of Treated Water	Assuming sufficient storage is available, treated water from both constant rate pumping tests will be discharged to the ditch after the constant rate pumping tests at PW-1 and PW-2 and after receiving the data from samples of the treated water.	2 days[2]
Data Management, Evaluation, & Reporting	Data from hydraulic testing, soil characterization and pre-construction verification sampling will be received and validated (as specified in the Work Plan) and incorporated into a report documenting the work performed and the results.	3 months

Notes:

1. Specified durations are estimated for each activity. In addition, the activities will be performed in the order listed, but some activities may overlap and/or may not be performed immediately upon completion of the preceding activity.
2. Durations for discharge of treated water are from receipt of laboratory data for samples collected of the treated water resulting from the previous activities.

Appendix B

Schematics of Typical Monitoring Well, Piezometer Construction, and Pumping Well Construction

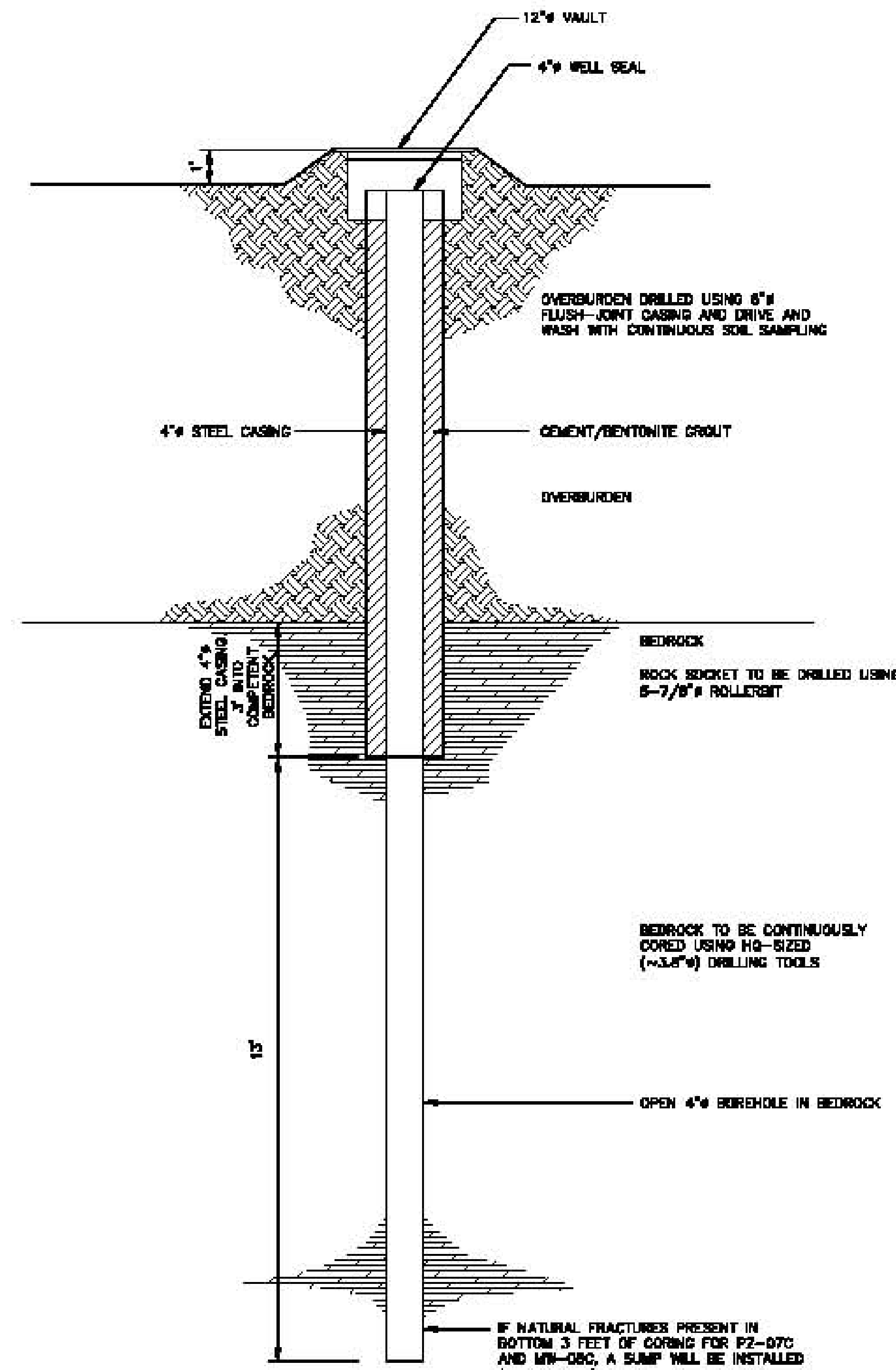


OVERBURDEN PIEZOMETER/MONITORING WELL (PZ-07B, PZ-21A, PZ-21B, MW-32A, AND MW-32B)

NOT TO SCALE

NOTES:

1. TOP OF SCREENED INTERVAL FOR SHALLOW OVERBURDEN ('B') PIEZOMETERS/MONITORING WELLS WILL BE SET APPROXIMATELY 1 FOOT ABOVE OBSERVED WATER TABLE ELEVATION.
2. BASE OF SCREENED INTERVAL FOR DEEP OVERBURDEN ('A') PIEZOMETERS/MONITORING WELLS WILL BE SET AT TOP OF BEDROCK.



BEDROCK PIEZOMETER/MONITORING WELL (PZ-07C, MW-08C, MW-31C, AND MW-32C)

NOT TO SCALE

NOTES:

1. CASING FOR BEDROCK PIEZOMETER/MONITORING WELL WILL BE SET A MINIMUM OF THREE FEET INTO COMPETENT BEDROCK; THE BOREHOLE WILL THEN BE EXTENDED ANOTHER 13 FEET BY BEDROCK CORING AND REAMING.
2. FOR PZ–07C AND MW–08C ONLY, IF NATURAL FRACTURES ARE OBSERVED IN BOTTOM 3 FEET OF CORING, CEMENT/BENTONITE GROUT WILL BE PLACED AT THE BOTTOM OF THE CORE HOLE AND A 3" DIAMETER 3 FOOT LONG STEEL SUMP WILL BE INSTALLED; OTHERWISE, CORE HOLE WILL REMAIN OPEN–HOLE CONSTRUCTION.

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FLETCHER'S PAINT WORKS AND STORAGE FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

PIEZOMETER/MONITORING WELL DETAILS

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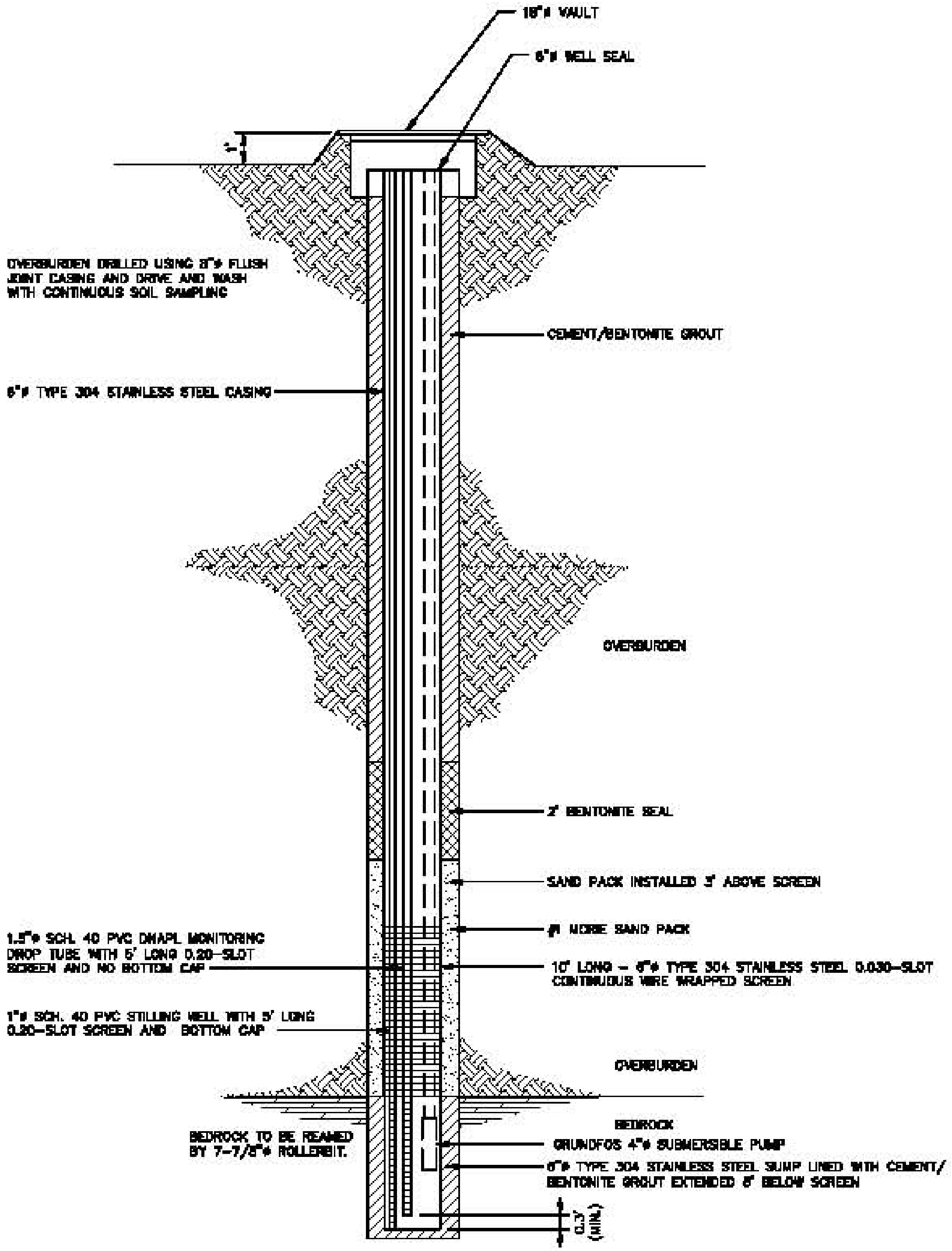
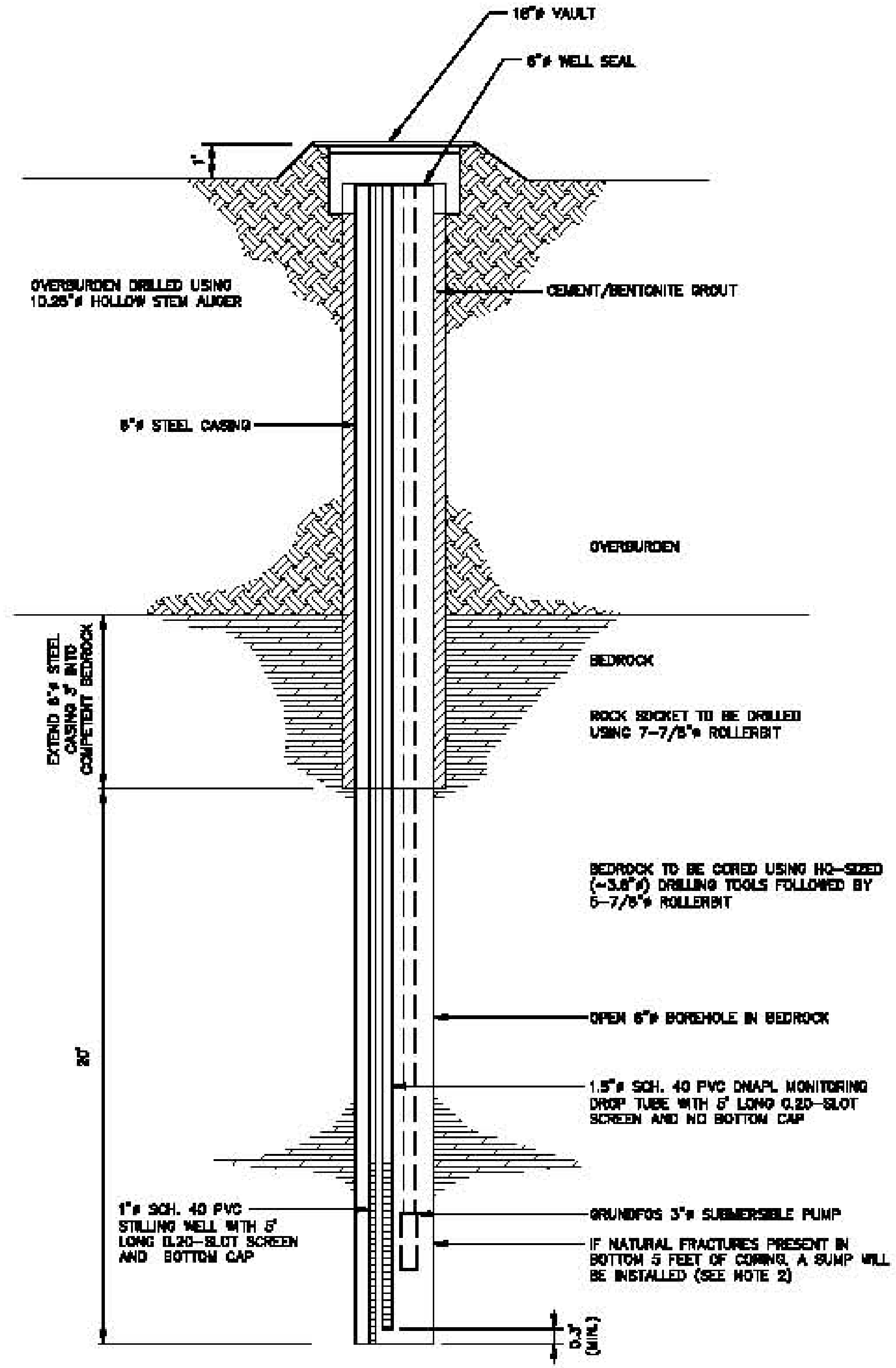
FIGURE **B-1**





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PROPOSED OVERBURDEN PUMPING WELL (PW-1)

NOT TO SCALE

NOTES:

1. BOREHOLE WILL BE DRILLED TO BEDROCK AND EXTENDED ANOTHER 5 FEET BY BEDROCK REAMING.
2. BOTTOM OF SCREENED INTERVAL WILL BE SET AT TOP OF BEDROCK.
3. A 5-FOOT LONG GROUTED SUMP WILL BE INSTALLED ON THE BOTTOM OF THE WELL.

PROPOSED BEDROCK PUMPING WELL (PW-2)

NOT TO SCALE

NOTES:

1. CASING FOR BEDROCK PUMPING WELL WILL BE SET A MINIMUM OF THREE FEET INTO COMPETENT BEDROCK. BOREHOLE WILL THEN BE EXTENDED ANOTHER 20 FEET BY BEDROCK CORING AND REAMING.
2. IF NATURAL FRACTURES ARE OBSERVED IN BOTTOM 5 FEET OF CORING, A SUMP WILL BE CONSTRUCTED BY GROUTING THE BOTTOM 5 FEET OF THE CORE HOLE AND REAMING WITH 5-7/8" DIAMETER ROLLER BIT; OTHERWISE, BOREHOLE WILL REMAIN OPEN-HOLE CONSTRUCTION.

FLETCHER'S PAINT WORKS AND STORAGE
FACILITY SUPERFUND SITE
MILFORD, NEW HAMPSHIRE

PUMPING WELL DETAILS

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FIGURE
B-2

Appendix C

Pumping Test Standard Operating Procedures

ARCADIS
Infrastructure, environment, facilities

Imagine the result

PUMPING TEST
STANDARD OPERATING PROCEDURES

Rev. #: 01

Rev Date: September 2008

Approval Signatures

Prepared by: ______________________________ Date: September 29, 2008

Reviewed by: ______________________________ Date: September 29, 2008
(Technical Expert)

I. Test Design

In general conventional hydraulic testing is conducted to provide answers to questions related to water supply problems. Tests are conducted over longer periods of time and provide estimates of hydraulic conductivity values averaged over large aquifer volumes. These tests tend to underestimate the highest hydraulic conductivity values and overestimate the lowest.

When conducting tests for remediation hydrogeology purposes it is important to indentify aquifer heterogeneities which ultimately control the transport of contaminants and reagents distribution within the aquifer. Short-term tests may help identify particular depositional elements and hydraulic conductivity trends and variability associated with facies changes in the aquifer. Data collected from short-term test can then be correlated with detailed hydrostratigraphic information to assist in the development of conceptual site models that describe the transport of contaminants and distribution of reagents.

1. Understand Aquifer Conditions

An aquifer (or permeable zone) pumping test is conducted in order to determine the hydraulic properties (transmissivity, hydraulic conductivity, storage coefficient, leakage, boundaries, anisotropy) of a water-bearing zone or system (including confining beds). Proper design of a pumping test requires a general understanding of the potential hydrologic system prior to the test, so that suitable data are collected to evaluate system parameters. The designer of the test must first develop an appropriate set of assumptions (conceptual model), either taken from previous tests in the immediate area or from well logs and an assessment of the site features that can affect the test (soil or rock types, depth to water, surface- water bodies, existing wells, storm drains). This conceptual model will then help the designer anticipate the necessary design factors such as: number of wells, depth and placement of wells; pumping rate(s); frequency of water-level measurements; and length of pumping. These factors will help the designer determine from the test results the effects of recharge and restrictive boundaries, aquifer geometry, secondary porosity effects (fractures, solution channels), the nature and extent of potentially confining layers, and aquifer interconnections.

2. Estimate Aquifer Parameters

Although the objective of a pumping test is to determine the principal aquifer parameters, the conceptual model requires a prediction of some of these parameters for the design process (i.e., observation well number and spacing requires approximate transmissivity and storage coefficient values). Hydraulic conductivity may be estimated from textural or hydraulic testing of aquifer materials in the laboratory, or from data collected and observations made during drilling or well development (see Driscoll, 1986). Considerable experience is needed to apply these methods for anything but preliminary estimating purposes. Therefore, use as many approaches as possible when making these estimates and remember that they are only estimates. Be ready to adjust preliminary estimates as more information becomes available throughout the process.

For larger tests (and thus larger pumping wells), potential casing storage effects and well (friction and formation) loss may need to be calculated prior to the test. Also, optimum pump size may need to be calculated. These will require an estimate of specific capacity, which is the well discharge rate per unit of drawdown measured at a given time. Specific capacity is typically determined from a step-drawdown test. An added benefit to conducting a step-drawdown test is the graphical results can also be used to calculate transmissivity (but not storage coefficient) in addition to well losses (see Section B.9).

3. Locate the Pumped Well

At many sites, the pumping well location is predetermined because an existing well suits the needs of the test, or the hydraulic properties of a specific location must be measured. If the pumping well location can be selected with relative freedom, the following criteria can be used as a guide for its installation:

a) where the hydrogeology represents the area of interest;

b) proximity to existing wells that could be used as observation wells (see guidelines 5, 6 and 7 below);

c) within the targeted contaminant plume whenever possible;

d) outside the contaminant plume if the system is areally homogeneous (or nearly so) and pumping of contaminated water poses an insurmountable problem;

e) away from groundwater system boundaries (assuming their approximate position is known) when the test purpose is solely to measure aquifer storage and transmission properties;

f) close to groundwater system boundaries (assuming their approximate position is known) when requiring boundary location, orientation (both positive and negative boundaries), or degree of connection (positive boundaries);

g) away from surface features that could obscure the data (for example, surface-water bodies) and away from areas subject to heavy-equipment traffic (i.e., railways and highways) that would put unpredictable stress on the aquifer, unless desiring specific information about the interrelationship of the groundwater system and surface features;

h) away from other producing wells that may not be shut down and may affect test data; and

i) where the site is safely and easily accessible to equipment and personnel.

Although these guidelines generally support test success, strictly adhering to them may produce conflicting test designs. Resolving these design conflicts requires good judgment based on a clear understanding of the test priorities and an appropriate knowledge of the local groundwater system.

4. Design the Pumped Well

a) The casing must accommodate the pump used for the test and allow ample additional space for measuring equipment.

b) The pumped well should be as efficient as possible through sound drilling practices, installation, and construction. A wire-wrapped screen and site-specific filter pack, designed from a sieve analysis, should be used to reduce factors that will mask true aquifer response.

c) If possible, a stilling pipe should be installed in the pumped well for making water- level measurements. The stilling pipe will dampen water-level fluctuations caused by pump vibration, eliminate measurement errors associated with cascading water, and isolate pressure transducers from pressure transients near the pump intake.

d) Generally, the screen in the pumped well should fully penetrate the tested zone to eliminate the complicated data analysis and interpretation required to correct for partial penetration effects (induced vertical flow component in addition to radial flow), with the following two exceptions:

   1) if the screen would form a conduit capable of transmitting chemicals from a contaminated horizon to a clean horizon; or

   2) when attempting to determine an aquifer's vertical anisotropy (ratio of vertical to horizontal hydraulic conductivity). This determination is necessary if remediation well capture zones will not affect the full thickness of the aquifer.

For these two conditions, the pumped well should only penetrate the contaminated portion of the aquifer. In addition, cost considerations may limit full penetration of the tested zone.

e) The pumped well must be fully developed to maximize the pumping rate from wells with limited available drawdown, simplify data interpretation and assure that no additional development occurs during the test.

f) Often, pumping wells are later used as monitoring or recovery wells. Such wells should be designed according to the requirements of the particular application without compromising the aforementioned standards for pumped wells.

5. Determine the Number of Observation Wells

Observation wells help quantify the size, shape, position, and rate of change of the cone of depression formed by pumping, making it possible to determine aquifer parameters. Adding wells increases the amount and accuracy of information acquired, and improves confidence in the data. The number of observation wells selected, however, must balance the information needs with the cost of constructing them.

Without observation wells, only transient analysis (time-drawdown) methods may be used to determine aquifer properties, and only transmissivity and hydraulic conductivity can be determined. A single observation well makes it possible to determine storage coefficient, but data analysis is still restricted to transient methods. Two or more observation wells permit the use of distance-drawdown methods of analysis, greatly improving the accuracy of aquifer parameter estimates. Distance-drawdown analysis is especially important whenever transient analysis methods are apt to produce erroneous results, as often occurs in unconfined aquifers, tight sediments, leaky aquifers, and aquifers with boundaries near the pumped well. Therefore, when possible, use at least two observation wells during a pumping test. Determining parameters such as leakage/delayed yield and anisotropy usually require more than two observation wells.

6. Design the Observation Wells

a) The observation well diameter must be large enough to accommodate instrumentation used to measure water levels and small enough that the volume of water in the well does not cause a time lag in responding to aquifer drawdown changes.

b) Unlike the pumped well, observation wells need not be highly efficient, just open enough to reflect pressure changes that occur in the aquifer. Thus, inexpensive construction materials such as slotted screens may be used (unless they will be used later as monitoring, recovery, or injection wells). Yet, to accurately represent the potentiometric changes that may differ vertically in the aquifer, the well intake must be open to the aquifer from top to bottom. This objective can be achieved with moderate well development. Techniques such as surging and bailing, which provide modestly effective development, can be used.

c) Generally, observation well screens should be fully penetrating to eliminate complications in data interpretation caused by partial penetration. As with the pumping well, the exceptions to this rule are:

   1) Avoid fully penetrating screens where they would create a conduit capable of spreading contamination;

2) Use short screens to assess vertical anisotropy at discrete elevations in the aquifer.

Short screens are appropriate for observation wells installed in aquitards that are being used to assess connectivity, recharge, or delayed yield factors.

As stated above, fully penetrating wells will simplify the data analysis because hydraulic theory for fully penetrating systems is simpler than that for partially penetrating ones. Theory also predicts that, for a confined aquifer, an observation well will show fully penetrating response if either it or the pumped well is fully penetrating. That is, in theory, both need not be fully penetrating --it is sufficient that just one or the other be fully penetrating to observe the simplified fully-penetrating response. In practice, however, it is preferable that both the pumped well and the observation well be fully penetrating, if possible. In aquifers where hydraulic conductivity varies substantially with depth, it is possible that a fully penetrating response would not actually occur unless both the pumped well and observation well were fully penetrating.

7. Situate the Observation Wells

a) Lateral Distribution

When using two observation wells, they should be positioned along a straight line radiating from the well. Accurately assessing horizontal anisotropy or near-well boundaries requires three pairs or sets of observation wells positioned along three different lines emanating from the well. If the principal axis of anisotropy is known, two sets of observation wells will suffice, one along the principal direction of anisotropy and one perpendicular to it. For example, if a fractured rock aquifer is known to be more permeable north-south than east-west, one set of two or more observation wells would be installed on a line north (or south) of the pumped well and another set along a line east (or west) of the pumped well.

In theory, single wells placed on three different lines emanating from the pumped well are sufficient to assess horizontal anisotropy. In practice, however, other heterogeneities can influence drawdown readings enough to bias the calculated anisotropy if just a single well is used along each line. Therefore, it is preferable to use pairs of wells whenever possible.

b) Well Spacing

Observation wells along a particular line from the pumped well should be spaced logarithmically with the distance to each successive observation well approximately double that to the preceding well. For example, three observation wells may be placed at distances of 10 ft, 20 ft, and 40 ft from the pumped well, or 50 ft, 100 ft, and 200 ft from the pumped well.

There are advantages and disadvantages to locating observation wells either near to, or far from, the pumped well. Distance drawdown analysis methods tend to integrate aquifer properties over the area spanned by the observation wells, so distant wells tend to yield aquifer parameters representative of a broad area of aquifer. At great distances, however, wells may exhibit drawdowns so small that they are difficult to measure accurately or analyze confidently. On the other hand, observation wells installed near the pumped well show more substantial drawdown but tend to reveal aquifer properties on a smaller scale. Situating observation wells, therefore, depends on the type of information required. For contamination investigations of small plumes, closely spaced observation wells provide satisfactory data.

The data set will be more reliable if substantial drawdowns can be attained in the observation wells. This is accomplished by maximizing the flow rate and locating the observation wells sufficiently close to the pumped well. As a rule of thumb, the distance from the pumped well to the nearest observation well should not exceed the square root of the expected radius of influence of the pumped well. R can be determined from:

$$R = \sqrt{\frac{0.04Tt}{S}}$$

where

R = radius of influence in ft

T = estimated transmissivity in ft^2/day

t = pumping test duration in days

S = storage coefficient

For example, in tight sediments, if the expected radius of influence is less than 100 ft, at least one observation well should be located within 10ft of the pumped well.

Be aware that the oft-repeated recommendation to locate the nearest observation well one or two aquifer thicknesses from the pumped well is actually a generalization (not entirely correct) for locating partially-penetrating observation wells away from a partially-penetrating pumping well. The actual radial distance for a partially-penetrating observation well must take into account anisotropy, as follows:

$$r = \frac{1.5b}{\sqrt{\frac{K_z}{K_{xy}}}}$$

where

r = radius from pumping well

b = thickness of aquifer

K_z = vertical hydraulic conductivity

K_{xy} = horizontal hydraulic conductivity

In most instances, and especially in unconfined or tight sediments, use closely spaced observation wells and eliminate partial penetration effects by using fully penetrating wells, or compensate for partial penetration effects by determining the anisotropy of the aquifer.

c) Vertical Distribution of Observation Wells

Generally, make sure that observation well screens are located in the pumped aquifer and fully penetrate it. To determine vertical anisotropy, however, screens must only partially penetrate the aquifer. For this determination, install observation wells in pairs at the same location, with one well screened in the pumped interval and the other screened in an unpumped interval of the aquifer to get a three-dimensional view of the pressure reductions caused by pumping.

If pumping is expected to induce leakage across an aquitard and if the leakance must be determined, place one or two piezometers in the aquitard to assess the magnitude of the drawdown, if any, created by the pumped well. Aquitard-monitoring wells should have short screens approximately centered in the aquitard, to keep the screen as far as possible from the top and bottom of the aquitard. Ideally, an aquitard observation well should be drilled at the same location as an observation well completed in the pumped aquifer.

8. Establish the Pumping Test Duration

a) The duration of pumping tests can range from a few hours to a few weeks depending upon the nature of the formation and the type of information required. For example, in highly transmissive confined sediments, if only near-well transmissivity must be known, a 2-hour test might suffice. However, to acquire information about boundaries or leakage, or if sediments are tight or unconfined, a much longer test is required. The preliminary test of the pumped well (Section B.9) will help in planning the test length.

b) For confined aquifers, a test duration of 24 to 48 hours will generally provide the information required.

c) Longer tests are required for unconfined aquifers because the cone of depression expands more slowly and delayed-drainage effects retard the response of the aquifer to pumping. Plan to conduct pumping tests in unconfined aquifers for 3 days or longer.

d) If leakage effects among aquifers must be determined, a longer test is appropriate. For example, under confined conditions, it may be desirable to extend the test to two or three days.

e) Economics may dictate curtailing the length of the pumping test if treating or storing pumped water is expensive. If water disposal is inexpensive, however, it makes sense to extend the test because the cost of the additional pumping and monitoring required is generally nominal.

9. Select the Appropriate Flow Rate and Measurement Device

a) The objective of the pumping test is to stress the aquifer sufficiently to obtain a meaningful, measurable response. Generally, the magnitude of the drawdown response in most observation wells is small. Thus, in most aquifer tests, design the well and pump intake in such a way that a sufficient stress is placed on the aquifer system that can be measured at a distance.

b) Select the pumping rate on the basis of a preliminary test (such as a step-drawdown test, Section B.9) so that the rate can be sustained by the pump for the duration of the test. The rate should not be so large that the water level is drawn down into the screen area, causing cascading effects and entrained air; under no circumstances should the water level be drawn down to the water entry of the pump or tail pipe.

c) Small variations in the discharge rate create large errors in the calculation of aquifer parameters. Therefore, sustaining a constant discharge rate is more important than knowing the exact rate with great accuracy. Accordingly, maintain the flow rate as closely as practical to a constant value, usually within ±1 percent or less. This can be achieved only if the flow rate can be measured precisely and adjusted easily as needed.

d) Always operate the pump against a partially closed valve so that, as drawdown increases during the test, a compensating reduction in back pressure is achieved by gradually opening the valve. The correct valve and flow measurement method are critical to this requirement. Select a valve that can be opened or closed in tiny increments to ease flow-rate control. A ball valve that opens fully or closes fully with a single 90-degree turn of a handle is undesirable because careful adjustments are difficult to achieve. A better choice is a gate valve that requires several 360-degree turns to open or close.

e) Flow measurement devices are typically based on three principles; head-type (orifice, venturi), velocity-type (magnetic, ultrasonic), and displacement-type (rotor, paddlewheel). Measurement devices/methods for a pumping test, in order of preference, are as follows:

1) Orifice weir with manometer (see Driscoll, pg 537): This is the best method of measuring the flow rate because it is precise, allows instantaneous reading of the flow rate so that adjustments can be made readily, and is relatively “low-tech”. While most orifice weirs accommodate higher flow rates, small-scale versions can be made for flows as small as a few gallons per minute. Such custom-made meters can be calibrated easily in the field with a bucket and stop watch. Installing a totalizing meter in line with and upstream from the orifice weir provides assurance that the total discharge for the test is calculated accurately. After completing the test, total discharge volume is divided by test duration to determine average flow rate.

2) Instantaneous (ultrasonic) flow meter: non-invasive, can be equipped with a data logger. Some meters may not respond properly when pumping sediment-laden water or two-phase fluids like hydrocarbons and water.

3) Paddlewheel totalizing meter: shows total volume pumped. When using this type of meter, flow rate must be determined by taking consecutive readings and dividing by the time between them. Accuracy may vary from one meter to another. Also may not respond properly when pumping sediment-laden water or two-phase fluids. Meter inaccuracy at low flow rates can be allayed by installing a flow restrictor (such as manufactured by Clack Corporation) upstream of the meter. The restrictor creates enough back pressure on the pumping unit to minimize flow rate fluctuations.

4) Bucket, or other container of known volume, and stop watch. For low flows, this procedure is about as accurate as any for determining the flow rate. It also serves as a reliable calibration tool for other flow measurement devices.

Other methods of measuring flow rate involve using various types of weirs, flumes, and open-discharge pipes generally do not provide the precision required for controlling the flow rate during a constant-rate pumping test.

10. Select the Pump

a) The pump used must have sufficient capacity to maintain the required discharge throughout the constant-rate portion of the test and to produce the various flow rates required for the step-drawdown test.

b) The pump should be capable of delivering the planned discharge rate at pressures substantially higher than the apparent nominal pressure required to lift water to the surface and overcome friction losses in the piping system. Pumping against a high head such as 60 to 100 psi tends to reduce discharge rate variations. It also permits operating the pump against a partially closed valve, creating additional head to help minimize flow-rate fluctuations during the test.

c) Submersible or turbine pumps driven by electric motors are ideal for conducting pumping tests because (barring spikes or storms) they run at nearly constant rates, producing generally uniform flow. Turbine pumps driven by gasoline or diesel engines, however, cause greater flow-rate variations because engine output can vary with fuel mixture, and air temperature and pressure.

d) The pump should be equipped with a check valve so that water in the column pipe and discharge pipes doesn't siphon back into the well following pump shut off. This prevents a sudden charge of water from obscuring the early recovery data and making analysis more difficult.

11. Plan for Pumped Water Disposal

a) Discharge pumped water so that pumped aquifer zones are not recharged. To accomplish this, pipe water to nearby storm or sanitary sewers, or lined surface-water bodies. If these options are not available, arrange to spread the discharge water on the ground sufficiently far from the pumping test site so that infiltration will not affect the test results.

b) If the water quality is such that direct discharge is not permitted, treatment may be necessary. Occasionally, water treatment facilities are already available on site. Alternatively, it may be possible to arrange for temporary treatment equipment just for the pumping test. If disposal during the test is not possible, the fluid can be discharged to containers such as frac tanks temporarily. Provisions must be made for the appropriate number and size of containers to handle the volume of water pumped during well development, step-drawdown testing, and constant-rate testing, plus a safety margin.

c) Discharge water must be disposed according to all applicable laws and regu1ations. Contact the governing agencies to determine which restrictions apply.

d) ARCADIS should not be responsible for signing manifests and should not "take possession" of discharged water.

12. Check for Casing Storage

Casing storage effects will render useless the early time/drawdown data from pumping tests. The larger the well diameter and the lower the specific capacity, the longer casing storage effects persist. Data recorded before casing storage effects end (at t_c) cannot be analyzed by any method.

The duration of the casing-storage affected portion of the test can be estimated as follows:

$$t_c = \frac{0.6\left(D^2 - d^2\right)}{Q/s}$$

where

t_c = duration of casing storage effect ('critical time'), in minutes

D = inside diameter of well casing, in inches

d = outside diameter of pump column pipe, in inches

Q = flow rate, in gpm

s = expected drawdown in the pumped well, in ft

Before conducting the test, it is important to estimate t_c. If the value is large, take steps to minimize storage effects if possible. For example, a packer may be installed with the pump column pipe to keep the water standing in the well casing from being removed from the well. If this is done, the packer must be specially designed to permit measurement of the hydraulic pressure in the well just under the packer. Alternatively, it may be possible to install ballast material alongside the column pipe to take up space and reduce the volume of water stored in the casing. For example, a 3.5-inch OD PVC pipe run alongside the column pipe in a low-yielding, 4-inch well, can reduce the duration of casing storage effects by 75 percent.

To demonstrate the significance of casing storage, a 4-inch test well in tight sediments with 1.25-inch column pipe producing 2 gpm with 30 ft of drawdown results in the following calculation:

$$t_c = \frac{0.6\left(4.026^2 - 1.66^2\right)}{2/30}$$

= 121 minutes

Thus, the first two hours of test data from this well cannot be analyzed.

In filter-packed wells, if water in the filter pack can drain quickly into the well (such as in wells that are screened across the water table), the equation for t_c must be modified to account for filter pack storage. The accomplish this, the term

$$D^2 - d^2$$

is replaced by

$$\left(D^2 - d^2\right) + S_y\left(B_d{}^2 - C_d{}^2\right)$$

where

B_d = diameter of borehole, in inches

C_d = outside diameter of casing, in inches

S_y = short-term specific yield of filter pack material --approximately 0.1 or 0.15

II. Pretest Activities

a) Unless installed specifically for the test, sound all wells for use in the test to verify well depth. (Do not use water level meters for this purpose, because some meters have probes that leak and trap water when subjected to excessive pressure.) Also, if adequate connection to the aquifer is suspect, conduct a slug test (either 'in' or 'out' - attempt to change the water level by at least 2 feet) in the observation wells. If the water-level response is too sluggish or no response is apparent, redevelop the well.

b) Label all wells (temporarily, if necessary) for quick and easy identification throughout the test.

c) Unless previously verified, measure the distance of all observation wells from the pumping well to the nearest foot.

2. Select Appropriate Water Level Measuring Devices

a) Pressure Transducers and Data Logger Combination

Transducers connected to electronic data loggers provide rapid water-level measurements with accuracy and ease. Some electronic data loggers (i.e., Hermit) collect and store data from a number of input channels (downhole pressure transducers plus atmospheric pressure) to provide water-level measurements in multiple within several hundred feet radius of the data logger, while others consist of a single logging transducer (i.e., Troll™, Levelogger™). Typical loggers take readings at preprogrammed linear or logarithmic intervals. If desired, data can be transferred to a personal computer for processing.

Small-diameter transducers (typically 0.5 to 0.75 in) are available that cover a range of pressures. Because they yield readings accurate to a percentage of their pressure range (usually about ±0.1 percent of the range in the center of that range, and ±0.2 percent near the limits) transducers that span a wide pressure range have lower absolute accuracies than those that span a narrow range. For example, a typical transducer with a 5 psi range detects water-level changes over a 11.6 ft with an accuracy of ±0.01 ft, whereas, a transducer with a 15 psi range detects changes over a 34.7 ft with an accuracy of ±0.03 ft. Thus, to ensure the greatest accuracy, select the transducer with the pressure range that most closely encompasses the anticipated drawdown or water-level change. Furthermore, confirm transducer water-level measurements throughout a test by manually taking regular water-level readings with a water level meter.

Caution: To prevent transducer malfunction, do not submerge transducers in excess of their operating range.

b) Water Level Meters, Interface Probes

These devices provide quick and easy water-level measurements with reasonable accuracy. They employ a sensor that is lowered into a well on the end of a marked cable (typically imprinted in feet and hundredths of a foot). When the sensor contacts water, a circuit is completed, activating a light, audio signal, ammeter, or digital display in the cable reel or housing. However, because the measurements are manual, the speed of readings cannot match those of a pressure transducer with a data logger. Thus, a water level meter is most useful in taking correlative, manual measurements in wells as a backup and for data checking, as well as measuring wells outside the active observation well network.

When appropriate, one water level meter should be used to take readings in all wells. If more than one meter is used to make site-wide water-level measurements, record the serial numbers and make comparison measurements within a single well to calibrate to a common standard.

c) Wetted Steel Tape

When using a steel tape, attach a weight to the bottom, wipe dry and coat the lower 2 to 3 feet with carpenter's chalk or water-soluble ink from a felt-tip marker, lower the tape into the well until part of the coated section extends below the water level, hold one of the major division (e.g., foot) markings at the predetermined measuring point, and record this reading. After withdrawal, read the wetted line on the coated section to the nearest 0.01 ft. Subtract this reading from the mark held at the measuring point; the difference is the actual depth to water.

A wetted steel tape is accurate and reliable, and is useful to verify and calibrate readings from other instruments. The procedure, however, is more time-consuming than others, limiting its usefulness during the early portion of pumping test when many rapid measurements are required. Furthermore, the approximate depth to water must be known in advance to ensure that part of the chalked section is submerged to produce the wetted line.

3. Verify Measuring Device Accuracy

Test pressure transducers and data logger readings using a bucket or barrel filled with water. Submerge each transducer, accurately measure the water head above the transducer, and compare the measurement to the data-logger reading. Check transducer response to changing heads by raising the transducer a certain distance, observing the change in the datalogger reading, and then measuring the distance with a standard steel tape. Water level meters should be in good working condition and calibrated, ensuring there are no breaks or splices in the cable.

4. Establish a Reference Point for Measuring Water Levels

At each well, establish and clearly mark the position of the selected reference point (often the north side, top of the casing). Determine the elevation of this point, record it, and state how this elevation was determined. This elevation point is important to establish the position of the piezometric surface, so it must be determined accurately.

5. Record Background Water Levels

To establish local trends, measure groundwater levels in all test wells and on-site surface water levels at regular intervals for several days before pumping any of the test wells. Although two days preceding the test may be enough (this meets the standards of some regulators), ideally the period of time should be at least equal to the length of the pumping test (three days to a week is optimum). Unless extreme variations are expected, such as significantly increased stream discharge in response to off-site precipitation, only surface water bodies within the radius of influence of the pumping well need to be monitored. A well outside the radius of influence may provide valuable information about water-level trends if monitored before, during, and after the pumping test. In areas that could be influenced by tidal fluctuations, collect information regarding local tidal variations before, during, and after the test.

If levels in the zones to be monitored during the test might be affected by pumping of other nearby wells, gather information about the discharge rates and operating times of those wells. Also, monitor water levels for a sufficient period before the test to evaluate the influence of nearby wells. Water-level monitoring should be done far enough in advance to allow time to negotiate with well owners and take appropriate action. If possible, arrange to have nearby wells shut down or pumped at a constant rate to ease data interpretation.

6. Record Barometric Pressure

Atmospheric-pressure changes can cause water level changes in confined or semi-confined aquifers, leading to erroneous conclusions about aquifer parameters. To correct for these changes, the barometric efficiency of each appropriate aquifer must be determined. Aquifer barometric efficiency (BE), a ratio of aquifer head change to atmospheric pressure change, can be calculated using:

$$BE = \left(\frac{\Delta h}{\Delta B_p} \right) 100\,\%$$

where

BE = barometric efficiency, in percent

Δh = change in water level resulting from change in atmospheric pressure, in feet

ΔB_p, = change in atmospheric pressure, in feet of water

To measure atmospheric pressure changes, either ensure that the dataloggers being used also measure barometric pressure, or obtain data from a nearby source. Barometric pressure must be recorded throughout the background water-level-measurement period and throughout the test. Ideally, barometric pressure and water-level measurements should be made during a time of significant atmospheric pressure change so their relationship can be more easily correlated.

Logging transducers with vented cables (e.g.: Troll, miniTroll) already account for barometric pressure and no additional adjustment is required.

7. Install a Rain Gauge

Heavy precipitation can cause a significant water-table rise in shallow aquifers. Note that rainfall data from nearby weather stations or airports may not be representative, because precipitation patterns may vary greatly over short distances. Therefore, when testing shallow aquifers, a rain gauge should be installed at the test site and monitored during rainfall. Keep in mind that storm sewers can channel large volumes of water rapidly to shallow aquifers.

8. Set-up: Remaining Equipment Required for Test

a) Keep sensitive electronic equipment away from devices that generate significant magnetic fields. For example, do not place data loggers near electric power generators or electric pump motors. Likewise, radio signals may cause dataloggers or computers to malfunction.

b) Secure data logger and transducer cables at the well head to prevent movement that would affect measurements. Mark a reference point on transducer cables and check regularly to detect slippage.

c) Provide adequate lighting for night readings.

d) Identify all equipment to be used in the test that will affect data. For example, describe (by serial number or otherwise) the pump, any isolation packers, water level meters, data loggers, rain gauges, barometers, flow meters, buckets or volumetric containers, watches, and steel tapes used.

e) Consider having backups for key equipment such as data loggers, generators, water level meters, etc.

9. Perform a Job Safety Analysis

To ensure that everyone is aware of the hazards associated with the work, and that each person knows his/her responsibilities during the preliminary and full-scale test, run through a JSA of the test before the start of pumping.

10. Conduct a Preliminary Pumping (Step-Drawdown) Test

Conduct a short-term preliminary test of the pumping well to estimate the hydraulic properties of the aquifer, estimate the duration of the test, and establish a pumping rate. A step-drawdown test is the most efficient preliminary test to use. If other constraints determine flow rate and the flow rate is sustainable, a step test is unnecessary.

The concept of step-drawdown testing in wells was first developed by Jacob (1947). He proposed that drawdown in a well has two components: formation loss (laminar, proportional to the discharge), and well loss (turbulent, proportional approximately to the square of the discharge). Jacob outlined a multiple-step drawdown test where discharge was increased at specific times, as if pumping of the well was held constant and additional wells were introduced at corresponding increases in pumping rates. Rorbaugh (1953) later noted that Jacob's assumption of second-order turbulent flow did not take into account that turbulence at low rates of discharge is not fully developed. Thus the exponent for turbulent flow should be expressed as an unknown constant. Taking this into consideration, the arithmetically-plotted results of a step-drawdown test can be used to select the discharge rate for a pumping test, determine drawdown for a given pumping rate and optimum pump depth, and even (with some minor calculations) estimate the transmissivity of the formation prior to the test. (This is also a good test for reliability of the flow meter.)

a) Select the pumping rates for the step-drawdown test based on:

   1) production capability estimates made during well development,

   2) prior pumping information,

   3) slug test data (for small wells), or

   4) a brief, preliminary rate test.

Step tests are most commonly run with three steps at 33, 67 and 100 percent or four steps at 25, 50, 75, and 100 percent of the anticipated maximum rate. Sometimes a step is added at 133 percent for a three-step test or 125 percent for a four-step test and the first step is dropped.

b) Conduct the step test, pumping at each level for 30 to 60 minutes. It is important to run the initial step long enough to establish that the effects of well storage have dissipated, with the remaining steps run for the same duration as the initial step. Although standard practice is to allow a recovery period after each step, practical experience shows that these individual recoveries are not necessary.

c) At the end of the step test, mark the setting of the discharge control valve corresponding to the flow rate for the full-scale pumping test. Secure the valve in that position with wire or tape to prevent inadvertent changes.

d) Allow sufficient time after completion for drawdown to return to static level. Although the time may vary, allow at least one day of recovery after the step-drawdown test has been completed before starting the constant-rate test.

11. Synchronize Watches

Just before the constant-rate test, watches and other time-measurement devices (i.e., dataloggers) should be synchronized so that the time of each reading, electronic and manual, can be referenced to the exact minute and hour that pumping started.

III. CONDUCTING THE TEST

1. Record Information

a) Use appropriate data forms

b) Record all required background information on logs before beginning the test

c) Record time as military (24-hour) time.

d) Ensure that everyone taking manual water-level measurements understands the units of measurement on the device or devices they will use.

2. Keep Pertinent Well Construction Details at Hand

To evaluate data plotted during the test, it may be necessary to have access to well construction information, such as the following:

- Lithologic logs;
- Well depths;
- Screen lengths
- Screen type (slotted, wrapped, opening size)
- Filter pack thickness and length
- Pumped well diameter
- Pump characteristics (performance, unit dimensions)
- Pump setting depth
- Topographic maps

3. Start the Test

a) Check all wells to confirm that water is at static level. Record the time since last pumping.

b) Make sure all field personnel are aware of predetermined starting time.

c) Start the pump and timing devices simultaneously. Use both an audible and visible signal to indicate the start of the test, especially if the distance between the pumped well and observation wells is large.

4. Measure Drawdown at Established Times

The widespread use of data loggers with extended memory precludes the older standard of using logarithmic time measurements. However, remember that rapid-frequency readings are needed early in the test in order to observe early effects of pumping and formation storage, plus effects of well construction. Water level measurements should be taken at least every five seconds.

Early time data are of greater importance when conducting pumping tests to identify aquifer heterogeneities and should be collected at short time intervals (< 1 sec) and considered as part of the pumping test analysis. Large data files can be generated and may need to be manipulated with text editors prior to importing data to other software such as Excel.

For manual observation well readings, the following schedule is suggested:

Elapsed Time	Interval Between Measurements (minutes)
0-5	1
5-15	2
15-60	5
60-120	10
120-300	30
300-1440	60
1440-end of test	240

Drawdown readings are sometimes difficult to record at the exact time required by the above schedules. If the designated time for a drawdown reading is missed, take a reading anyway and record the actual time. However, try to follow the established schedule as closely as possible to ease data plotting. Use the following table as a guideline for time measurement accuracy.

5. Check the Flow Measuring Device

Unrecorded fluctuations of pumped well discharge rate can make the test data difficult to interpret. Measure and record discharge every 5 minutes during the beginning of the test. When discharge becomes stable, reduce the frequency to hourly checks.

As water levels decline, the discharge rate may decrease, thus requiring adjustment. Whenever adjusting the flow rate, record water levels in the pumped well before and after each adjustment.

6. Monitor Fuel Levels

When using liquid-fuel-driven engines or generators, monitor and refill fuel tanks as needed to prevent premature termination of the test.

7. Plot Data to Evaluate Trends and Catch Aberrations

a) Begin to tabulate and graph the elapsed time, discharge rate, and pumped well drawdown as early as possible in the test, usually after the first hour of testing.

b) Prepare a plot of the log of drawdown (log10s) versus the log of the ratio of time since pumping started to the square of the distance from the pumped well to the observation well (log10t/r2) on arithmetic graph paper and maintain during the test. Compare this data to basic type curves to detect deviations that may be due to discharge variations or other changes in field conditions that need to be documented. A portable computer and printer ease this plotting for tests with many wells.

c) Keep the plots current throughout the test. This information supports informed, intelligent decisions about test progress and may signal anomalies such as equipment malfunctions or unacceptable flow rate variations. Analysis of these plots may suggest that more data is needed to substantiate conclusions about the groundwater system.

8. Collect Groundwater Samples and Measure Field Parameters

Samples of discharge water may provide valuable information about the nature of aquifer water quality as it changes during the pumping test. Depending on the site conditions, samples collected regularly throughout the test may signal proximity to a contaminant source, connection with surface water bodies, or other contributors to water quality change. The number of water samples needed and the frequency and time of their collection depends on both nearness to suspected or known water quality influences and the test budget.

9. Verify Measuring Device Accuracy

Recheck the accuracy of hand-held electronic water-level sounders before starting the recovery portion of the test. During pumping and recovery, check transducer accuracy periodically with reliable manual devices. Every hour or few hours is sufficient for most tests.

10. Measure Water Levels during the Recovery Phase at Established Times

Recovery of water levels following the pumping phase should be measured immediately upon pump shut down and recorded for a period of time equal to the pumping time, or until the water levels have reached 95 percent of the initial, pre-pumping static water level. Use the same drawdown measurement schedule that was used during pumping. A check valve should be used to prevent backflow of water in the riser pipe into the well, which could result in unreliable recovery data.

Recovery phase data may be easier to analyze because no discharge fluctuations occur, and pump-induced turbulence is not a concern in the pumping well. However, note that typically the calculated transmissivity from the pumping phase will be lower than that of the recovery phase due to the added turbulence and vertical flow components during pumping.

11. Record Observation of Pertinent Phenomena

Record any unusual events occurring just before or during the test that may affect test data, such as:

- Weather changes
- Heavy equipment (trains, etc.) passing through area
- Operation times of other wells
- Changes in pumping rate
- Equipment problems, and
- Earthquakes

IV. POST-TEST PROCEDURES

1. Document the "As-Built" Configuration of the Test

Describe the configuration of the test, the observation well locations versus the pumping well, water discharge, outside influences detected during the test, and any modifications to the original plan.

2. Verify Timing Device Agreement and Measuring Device Accuracy

Compare all clocks, watches, and data recorders for agreement and note any discrepancies, identifying the devices and where they were used. Compare manual measurements to datalogger measurements within wells to confirm accuracy of measuring devices.

3. Sound the Pumped Well

Determine if any aquifer material accumulated in the pumped well during the test. Sand or other material accumulating in the well during the test progressively blocks screen areas, reducing the effective aquifer penetration. If the effect of this condition is not taken into account, aquifer parameters calculated from test data will be wrong. Gradually decreasing aquifer penetration in a pumped well significantly complicates test data analysis. The wisest strategy, therefore, is to prevent infilling of screens by sufficient development of the pumped well.

4. Decontaminate All Equipment Contacting Site Groundwater and Soil

Use appropriate decontamination procedures.

5. Monitor Background Information as Long as Possible

If possible, continue to monitor groundwater levels, surface water levels, and barometric pressure data for several days after test completion. This information may reveal trends or relationships undetected before or during the test.

V. SPECIAL CONSIDERATIONS

1. Wells Containing Floating Nonaqueous Phase Liquids

It is best to use pressure transducers to measure water levels in wells containing floating product such as gasoline. Contact with floating product, however, may make transducers and cable unsuitable for future use. Thus, include the cost of replacing transducers (and perhaps cable) when calculating pumping test budgets. Otherwise, protect each transducer and cable assembly by encasing it in plastic tubing or pipe. Be sure that each protected transducer still can respond accurately to any pressure changes.

As an alternative to pressure transducers, make manual measurements (using a interface probe) of both the fuel level and water level individually. Then correct the observed thickness of floating product by its density to arrive at an effective pumping level. Measure product density in the field using a simple density balance (such as drilling fluid balance) or consult an appropriate API table. This manual procedure will work, but takes time and introduces additional measurement and computation errors.

2. Fill Materials

Occasionally, pumping tests are conducted in or adjacent to fill materials. In these circumstances, it is essential that the nature of the fill and possible extremes in heterogeneity be understood and incorporated into the design of the pumping test so that the resulting data set can provide the required information.

3. Karst and Cavernous Aquifers

Flow through the fractures and conduits within a karst aquifer system ranges from conduit to diffuse. Conduit flow describes flow through dissolution channels with velocities commonly high and turbulent. (The presence of conduits typically requires a dual-porosity model for characterization). Diffuse flow, on the other hand, refers to a slow, mostly laminar to slightly turbulent flow through a series of small, discrete pathways that are being enlarged through dissolution. Karst aquifers do not lend themselves to conventional pumping test layout, procedures, and analysis because flow can be dominated by discrete channels. The discrete nature of high-conductivity zones can range several orders of magnitude and thus hydraulic conductivity values vary according to the scale of measurement, from local to regional. Interpretation of pumping tests must take into consideration the portion of the aquifer being tested.

Additional background investigations may need to be conducted before a pumping test is conducted, in order to predict the connectivity of the wells within the test network. This may include borehole and surface geophysics, tracer (natural and introduced) testing, spring flow and water chemistry analysis, slug testing, and lineament analysis.

4. Fractured Aquifers

The challenge to conducting a pumping test within a fractured-rock aquifer is the continuity of fractures can vary significantly within an area and affect its ability to provide water in a consistent manner. Many fractured aquifers also exhibit a preferred permeability direction based on predominant fracture orientations. Recharge may also vary seasonally and cause production problems in low flow periods (low water level and low recharge). During these periods excessive drawdown may occur. Typically, sources completed in bedrock composed of shale, basalt, granite or any consolidated material can have fractured flow concerns.

For these aquifer systems, although a conventional pumping test approach is generally appropriate, more observation wells will be required to determine the anisotropy and to discern both near-well and distant responses. Also, step-drawdown test data provide valuable information in fractured aquifers because flow near the well in fractured aquifers may be mostly turbulent.

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